

Realtime and Embedded Specification for Java Version 2.0

Draft 24
Motion Picture Edition
JTRES Face-to-Face
6th of October 2015

Editor
James J. Hunt
aicas GmbH
Haid-und-Neu-Straße 18
D-76131 Karlsruhe, Germany

Copyright © 1999–2012 TimeSys
Copyright © 2012–2015 aicas GmbH
All rights reserved

The Realtime Specification for Java (RTSJ) is under development within the Java Community Process (JCP) by the members of the JSR-282 Expert Group (EG). This group, was lead by TimeSys Inc. Corporation, but has been taken over by aicas GmbH.

JSR-282 Expert Group Membership

James J. Hunt aicas GmbH
Benjamin Brosgol
Andy Wellings
Kelvin Nilsen
Ethan Blanton

Past Expert Group Members

Peter Dibble TimeSys
David Holmes Oracle

Table of Contents

Contents	i
List of Figures	xii
List of Tables	xiii
1 Introduction	1
1.1 Guiding Principles	2
1.1.1 Applicability to Particular Java Environments	2
1.1.2 Backward Compatibility	3
1.1.3 Write Once, Run Anywhere	3
1.1.4 Current Practice vs. Advanced Features	3
1.1.5 Predictable Execution	3
1.1.6 No Syntactic Extension	3
1.1.7 Allow Variation in Implementation Decisions	3
1.1.8 Interoperability	4
1.2 Areas of Enhancement	4
1.2.1 Thread Scheduling and Dispatching	4
1.2.2 Memory Management	5
1.2.3 Synchronization and Resource Sharing	5
1.2.4 Asynchronous Event Handling	5
1.2.5 Task Interruption	5
1.2.6 Raw Memory Access	6
1.2.7 Physical Memory Access	6
1.2.8 Modularization	6
2 Overview	7
2.1 Threads and Scheduling	7
2.2 Synchronization	9
2.2.1 Priority Inversion	9
2.2.2 Priority Inversion Avoidance	10
2.2.3 Execution Eligibility	11

2.2.4	Wait-Free Queues	11
2.3	Asynchrony	11
2.3.1	Asynchronous Events	12
2.3.2	Asynchronous Transfer of Control	13
2.3.3	Principles	13
2.3.3.1	Methodological Principles	14
2.3.3.2	Expressibility Principles	14
2.3.3.3	Semantic Principles	14
2.3.3.4	Pragmatic Principles	15
2.3.4	Asynchronous Realtime Thread Termination	15
2.4	Clocks, Time, and Timers	16
2.5	Memory Management	16
2.5.1	Memory Areas	16
2.5.2	Heap Memory	17
2.5.3	Immortal Memory	17
2.5.4	Scoped Memory	17
2.5.5	Physical Memory Areas	18
2.5.6	Budgeted Allocation	18
2.6	Device Access and Raw Memory	19
2.6.1	Raw Memory Access	19
2.7	System Options	19
2.8	Exceptions	20
2.9	Summary	20
3	Requirements and Conventions	21
3.1	Base Requirements	21
3.2	Modules	22
3.2.1	Base Module	22
3.2.2	Device Module	24
3.2.3	Alternative Memory Area Module	25
3.2.4	Optional Features	26
3.2.5	Deprecated Classes	27
3.3	Conditionally-Required Facilities	28
3.3.1	Options for Development Platforms	28
3.4	Required Documentation	29
3.5	Conventions	30
3.6	Definitions	30
4	Conventional Java Classes and Language	33
4.1	Scheduling	33
4.1.1	Priority	34

4.1.1.1	Setting Priority	34
4.1.1.2	Getting Priority	35
4.1.2	Thread Groups	35
4.1.3	Current Thread	36
4.2	Java Memory Model	37
4.3	InterruptedException	37
4.4	Memory Management	37
4.4.1	Memory Areas	37
4.4.2	Garbage Collection	38
4.4.3	Realtime Garbage Collections	38
4.4.3.1	Thread-Based Collectors	38
4.4.3.2	Allocation-Based Collectors	39
4.4.3.3	Alternatives to Garbage Collection	39
4.4.3.4	Developer Implementation	39
4.5	Summary	39
5	Realtime Threads	41
5.1	Overview	41
5.2	Semantics	42
5.3	Package <code>javax.realtime</code>	44
5.3.1	Enumerations	44
5.3.1.1	PhasingPolicy	44
5.3.2	Classes	46
5.3.2.1	ConfigurationParameters	46
5.3.2.2	RealtimeThread	49
5.4	Rationale	72
6	Scheduling	75
6.1	Overview	75
6.2	Definitions	77
6.3	Semantics	79
6.3.1	Schedulers	79
6.3.2	The Base Scheduler	80
6.3.2.1	Priorities	80
6.3.2.2	Dispatching	81
6.3.2.3	Parameter Values	83
6.3.2.4	Cost Monitoring and Cost Enforcement	85
6.3.2.5	Release of a Realtime Thread	87
6.3.2.6	Aperiodic Release Control	94
6.3.2.7	Sporadic Release Control	95
6.3.2.8	Release Control for Asynchronous Event Handlers	97

6.3.3	The Round-Robin Scheduler	99
6.3.3.1	Priorities	99
6.3.4	Managing Groups of Schedulables	100
6.3.4.1	Scheduling Groups	100
6.3.4.2	Processing Groups	100
6.4	Package javax.realtime	103
6.4.1	Interfaces	103
6.4.1.1	BoundSchedulable	103
6.4.1.2	RealtimeExecutionContext	103
6.4.1.3	Schedulable	103
6.4.2	Classes	112
6.4.2.1	Affinity	112
6.4.2.2	AperiodicParameters	121
6.4.2.3	FirstInFirstOutScheduler	129
6.4.2.4	ImportanceParameters	132
6.4.2.5	PeriodicParameters	134
6.4.2.6	PriorityParameters	141
6.4.2.7	PriorityScheduler	143
6.4.2.8	ProcessingGroup	146
6.4.2.9	ReleaseParameters	154
6.4.2.10	RoundRobinScheduler	161
6.4.2.11	Scheduler	165
6.4.2.12	SchedulingGroup	168
6.4.2.13	SchedulingParameters	170
6.4.2.14	SporadicParameters	172
6.5	Rationale	179
6.5.1	Multiprocessor Support	180
6.5.2	Impact of Clock Granularity	181
6.5.3	Deadline Miss Detection	181
7	Synchronization	183
7.1	Overview	183
7.2	Definitions	184
7.3	Semantics	184
7.3.1	Monitor Control	184
7.3.2	Priority Schedulers	185
7.3.3	Additional Schedulers	187
7.4	Package javax.realtime	188
7.4.1	Classes	188
7.4.1.1	MonitorControl	188
7.4.1.2	PriorityCeilingEmulation	190

7.4.1.3	PriorityInheritance	193
7.4.1.4	WaitFreeDequeue	194
7.4.1.5	WaitFreeReadQueue	195
7.4.1.6	WaitFreeWriteQueue	202
7.5	Rationale	208
8	Asynchrony	211
8.1	Overview	211
8.1.1	Events and Event Handling	211
8.1.2	Asynchronous Transfer of Control	212
8.2	Definitions	213
8.3	Semantics	214
8.3.1	Asynchronous Events and their Handlers	214
8.3.2	Active Events and Dispatching	216
8.3.3	Asynchronous Transfer of Control	217
8.3.3.1	Summary of ATC Operation	220
8.4	Package javax.realtime	223
8.4.1	Interfaces	223
8.4.1.1	ActiveEvent	223
8.4.1.2	AsyncTimable	225
8.4.1.3	BoundAsyncBaseEventHandler	226
8.4.1.4	Interruptible	226
8.4.1.5	Releasable	227
8.4.2	Exceptions	228
8.4.2.1	AsynchronouslyInterruptedException	228
8.4.2.2	Timed	233
8.4.3	Classes	235
8.4.3.1	ActiveEventDispatcher	235
8.4.3.2	AsyncBaseEvent	238
8.4.3.3	AsyncBaseEventHandler	242
8.4.3.4	AsyncEvent	253
8.4.3.5	AsyncEventHandler	254
8.4.3.6	AsyncLongEvent	260
8.4.3.7	AsyncLongEventHandler	262
8.4.3.8	AsyncObjectEvent	267
8.4.3.9	AsyncObjectEventHandler	269
8.4.3.10	BoundAsyncEventHandler	273
8.4.3.11	BoundAsyncLongEventHandler	275
8.4.3.12	BoundAsyncObjectEventHandler	277
8.5	Rationale	279

9	Time	281
9.1	Overview	281
9.2	Definitions	282
9.3	Semantics	283
9.4	Package javax.realtime	286
9.4.1	Classes	286
9.4.1.1	AbsoluteTime	286
9.4.1.2	HighResolutionTime	299
9.4.1.3	RelativeTime	307
9.5	Rationale	317
10	Clocks and Timers	319
10.1	Overview	319
10.2	Definitions	320
10.3	Semantics	321
10.3.1	Clock Model	321
10.3.2	Clocks and Timables	322
10.3.3	Timers	325
10.3.3.1	Counter Model	326
10.3.3.2	Comparator Model	326
10.3.3.3	Triggering	326
10.3.3.4	Behavior of Timers	327
10.3.3.5	Phasing	328
10.4	Package javax.realtime	329
10.4.1	Interfaces	329
10.4.1.1	AsyncTimable	329
10.4.1.2	Chronograph	329
10.4.1.3	Timable	332
10.4.2	Classes	332
10.4.2.1	Clock	332
10.4.2.2	OneShotTimer	338
10.4.2.3	PeriodicTimer	340
10.4.2.4	TimeDispatcher	348
10.4.2.5	Timer	350
10.5	Rationale	370
11	Alternative Memory Areas	373
11.1	Overview	373
11.1.1	Physical Memory	374
11.1.2	Stacked Memory	375
11.1.3	Summary	378

11.2	Definitions	379
11.3	Semantics	380
11.3.1	Allocation Execution Time	380
11.3.2	Allocation Context	381
11.3.3	The Parent Scope	382
11.3.4	Memory Areas and Schedulables	382
11.3.5	Scoped Memory Reference Counting	383
11.3.6	Immortal Memory	384
11.3.7	Maintaining Referential Integrity	384
11.3.8	Object Initialization	385
11.3.9	Maintaining the Scope Stack	385
11.3.10	The <code>enter</code> Method	386
11.3.11	The <code>executeInArea</code> or <code>newInstance</code> Methods	387
11.3.12	Constructor Methods for Schedulables	387
11.3.13	The Single Parent Rule	388
11.3.14	Scope Tree Maintenance	388
11.3.14.1	On Scope Stack Push of MA	388
11.3.14.2	On Scope Stack Pop of ma	389
11.4	Package <code>javax.realtime</code>	390
11.4.1	Interfaces	390
11.4.1.1	<code>MemoryAreaVisitor</code>	390
11.4.2	Classes	391
11.4.2.1	<code>HeapMemory</code>	391
11.4.2.2	<code>ImmortalMemory</code>	395
11.4.2.3	<code>MemoryArea</code>	397
11.4.2.4	<code>MemoryParameters</code>	410
11.4.2.5	<code>SizeEstimator</code>	416
11.5	Package <code>javax.realtime.memory</code>	420
11.5.1	Interfaces	420
11.5.1.1	<code>PhysicalMemoryCharacteristic</code>	420
11.5.1.2	<code>VirtualMemoryCharacteristic</code>	420
11.5.2	Enumerations	421
11.5.2.1	<code>PhysicalMemorySelector.CachingBehavior</code>	421
11.5.2.2	<code>PhysicalMemorySelector.PagingBehavior</code>	422
11.5.3	Classes	423
11.5.3.1	<code>LTMemory</code>	423
11.5.3.2	<code>PhysicalMemoryFactory</code>	429
11.5.3.3	<code>PhysicalMemoryRegion</code>	435
11.5.3.4	<code>PhysicalMemorySelector</code>	437
11.5.3.5	<code>PinnableMemory</code>	439

11.5.3.6	ScopedMemory	443
11.5.3.7	StackedMemory	467
11.6	The Rationale	478
11.6.1	The Scoped Memory Model	478
11.6.2	The Physical Memory Model	479
11.6.2.1	Problems with the RTSJ 1.0.2 Physical Memory Framework	481
11.6.2.2	The RTSJ 2.0 Physical Memory Framework	483
11.6.2.3	An example	484
12	Devices and Triggering	487
12.1	Overview	487
12.2	Definitions	488
12.3	Semantics	489
12.3.1	Raw Memory	489
12.3.1.1	Raw Memory Region	491
12.3.1.2	Raw Memory Factory	492
12.3.1.3	Stride	492
12.3.2	Direct Memory Access Support	492
12.3.3	External Triggering	493
12.3.3.1	Happenings	493
12.3.4	Interrupt Service Routines	496
12.4	Package javax.realtime.device	499
12.4.1	Interfaces	499
12.4.1.1	RawByte	499
12.4.1.2	RawByteReader	499
12.4.1.3	RawByteWriter	502
12.4.1.4	RawDouble	505
12.4.1.5	RawDoubleReader	505
12.4.1.6	RawDoubleWriter	508
12.4.1.7	RawFloat	511
12.4.1.8	RawFloatReader	511
12.4.1.9	RawFloatWriter	514
12.4.1.10	RawInt	517
12.4.1.11	RawIntReader	517
12.4.1.12	RawIntWriter	520
12.4.1.13	RawLong	523
12.4.1.14	RawLongReader	523
12.4.1.15	RawLongWriter	526
12.4.1.16	RawMemory	529
12.4.1.17	RawMemoryRegionFactory	530
12.4.1.18	RawShort	549

12.4.1.19	RawShortReader	550
12.4.1.20	RawShortWriter	553
12.4.2	Classes	555
12.4.2.1	Happening	555
12.4.2.2	HappeningDispatcher	562
12.4.2.3	InterruptServiceRoutine	564
12.4.2.4	RawBufferFactory	568
12.4.2.5	RawMemoryFactory	572
12.4.2.6	RawMemoryRegion	597
12.5	Rationale	599
12.5.1	Raw Memory	599
12.5.1.1	Direct memory access	601
12.5.2	Interrupt Handling	602
12.5.3	An Illustrative Example	604
12.5.3.1	Software architecture	604
12.5.3.2	Device initialization	606
12.5.3.3	Responding to external happenings	607
12.5.3.4	Access to the flash controller's device registers	608
13	System and Options	611
13.1	Overview	611
13.2	Semantics	611
13.2.0.5	RealtimeSystem	612
13.2.0.6	RealtimeSecurity	612
13.2.0.7	POSIX Signals	612
13.2.0.8	POSIX Realtime Signals	612
13.3	Package javax.realtime	613
13.3.1	Classes	613
13.3.1.1	GarbageCollector	613
13.3.1.2	POSIXRealtimeSignal	614
13.3.1.3	POSIXRealtimeSignalDispatcher	618
13.3.1.4	POSIXSignal	620
13.3.1.5	POSIXSignalDispatcher	626
13.3.1.6	RealtimeSecurity	628
13.3.1.7	RealtimeSystem	632
13.4	Rationale	637
14	Exceptions	639
14.1	Overview	639
14.2	Semantics	639
14.3	Package javax.realtime	641

14.3.1	Interfaces	641
14.3.1.1	StaticThrowable	641
14.3.2	Exceptions	645
14.3.2.1	ArrivalTimeQueueOverflowException	645
14.3.2.2	CeilingViolationException	646
14.3.2.3	DeregistrationException	647
14.3.2.4	InaccessibleAreaException	649
14.3.2.5	LateStartException	650
14.3.2.6	MITViolationException	651
14.3.2.7	MemoryInUseException	652
14.3.2.8	MemoryScopeException	652
14.3.2.9	MemoryTypeConflictException	653
14.3.2.10	OffsetOutOfBoundsException	654
14.3.2.11	ProcessorAffinityException	655
14.3.2.12	RegistrationException	656
14.3.2.13	ScopedCycleException	658
14.3.2.14	SizeOutOfBoundsException	659
14.3.2.15	UnknownHappeningException	660
14.3.2.16	UnsupportedPhysicalMemoryException	661
14.3.2.17	UnsupportedRawMemoryRegionException	662
14.3.3	Classes	663
14.3.3.1	AlignmentError	663
14.3.3.2	BacktraceManagement	664
14.3.3.3	IllegalAssignmentError	667
14.3.3.4	MemoryAccessError	668
14.3.3.5	ResourceLimitError	669
14.3.3.6	StaticOutOfMemoryError	670
14.3.3.7	ThrowBoundaryError	674
14.4	Rationale	676
15	Deprecated Classes	677
15.1	Overview	677
15.2	Semantics	677
15.3	Package javax.realtime	678
15.3.1	Interfaces	678
15.3.1.1	PhysicalMemoryTypeFilter	678
15.3.2	Exceptions	684
15.3.2.1	DuplicateFilterException	684
15.3.2.2	UnknownHappeningException	685
15.3.3	Classes	686
15.3.3.1	ImmortalPhysicalMemory	686

15.3.3.2	LTMemory	695
15.3.3.3	LTPhysicalMemory	701
15.3.3.4	NoHeapRealtimeThread	711
15.3.3.5	POSIXSignalHandler	714
15.3.3.6	PhysicalMemoryManager	721
15.3.3.7	ProcessingGroupParameters	730
15.3.3.8	RationalTime	739
15.3.3.9	RawMemoryAccess	739
15.3.3.10	RawMemoryFloatAccess	763
15.3.3.11	ScopedMemory	775
15.3.3.12	VTMemory	790
15.3.3.13	VTPhysicalMemory	795
15.3.3.14	WaitFreeDequeue	805
15.4	Rationale	806
16	Conformance, Compliance, and Portability	807
16.1	Overview	807
16.2	Semantics	807
16.2.1	Modules	808
16.2.2	Optionally Required Components	808
16.2.3	Deployment Implementation	808
16.2.4	Simulation Implementation	810
16.2.5	Documentation Requirements	810
16.3	Rationale	810
A	Bibliography	811

List of Figures

6.1	Sequence Diagram of Some Example Realtime Thread Releases	92
6.2	A State Chart for a Realtime Thread without a Deadline Miss Handler	93
6.3	A State Chart for a Realtime Thread with a Deadline Miss Handler .	94
8.1	The Event Class Hierarchy	215
8.2	States of a Simple AsyncBaseEvent	216
8.3	States of an ActiveEvent	218
10.1	Sequence Diagram for Using a Timer	324
10.2	Sequence Diagram for Realtime Sleep	325
10.3	States of a Timer	328
11.1	Manipulation of StackedMemory Areas	377
12.1	Raw Memory Interface	490
12.2	Event Classes	491
12.3	Happening State Transition Diagram	494
12.4	Interrupt servicing	495
12.5	Creating Raw Memory Accessors	600
12.6	Flash memory device	602
12.7	Flash memory classes	606
12.8	Sequence diagram showing initialization operations	606
12.9	Sequence diagrams showing operations to initialize the hardware device	607
12.10	The FMSocketController.handleAsync method	608
12.11	Application usage	609

List of Tables

3.1	RTSJ Options	26
5.1	Effect of PhasingPolicy on the First Release of a RealtimeThread with PeriodicParameters	45
6.3	AperiodicParameters Default Values	122
6.4	FirstInFirstOut Default PriorityParameter Values	129
6.5	PeriodicParameter Default Values	135
6.6	PriorityScheduler Default PriorityParameter Values	144
6.7	ProcessingGroup Default Values	148
6.8	ReleaseParameter Default Values	155
6.9	SporadicParameters Default Values	173
12.1	Property Array	575
12.2	Device registers	605
15.1	ProcessingGroupParameter Default Values	732
15.2	Properties Array	742

Chapter 1

Introduction

The goal of the *Real-Time Specification for Java* (RTSJ) is to support the use of Java technology in embedded and realtime systems. It provides a specification for refining the *Java Language Specification* and the *Java Virtual Machine Specification* and of providing an extended Application Programming Interface that facilitates the creation, verification, analysis, execution, and management of realtime Java programs such as control and sensor applications.

The Java Virtual Machine and the Java Language were conceived as a portable environment for desktop and server applications. The emphasis has been on throughput and responsiveness. These are characteristics obtainable with time-sharing systems. For this conventional Java environment, it is more important that each task makes progress, than that a particular task completes within a predefined time slot.

In a realtime system, the system tries to schedule the most critical task that is ready to run first. This task runs either until it is finished, or it needs to wait for some event or data, or a more critical task is released or a more critical task becomes schedulable after waiting for its event or data.

Realtime scheduling is commonly done with a priority preemptive scheduler, where tasks that have short deadlines are given higher priority than tasks that have longer deadlines. The programmer is responsible for encoding some notion of task importance to priorities. The goal is to see that all tasks finish within their deadlines. Scheduling analysis, such as Rate Monotonic Analysis, can be used to help determine this.

Many realtime systems have nonrealtime components, so it is desirable to be able to combine realtime and nonrealtime tasks in a single system. Realtime tasks are then given preference over nonrealtime tasks. For Java, this means that realtime tasks must be scheduled before threads with conventional Java priorities (1–10). Being able to synchronize between tasks, both realtime and conventional Java threads, adds additional requirements.

Providing realtime semantics and the additional programming interfaces required

is a core part of this specification. So much so that the original specification provided special memory areas to avoid the use of garbage collection. The availability of various techniques for realtime garbage collection has changed the state of practice since RTSJ Version 1.0. Though still part of the specification, these special memory areas are no longer central to it. Realtime scheduling and priority inversion avoidance for synchronization are the core of providing realtime response. These are provided through refinements to the base Java semantics and additional classes.

Realtime tasks can be modeled both with realtime threads and with event handlers. Realtime threads are much the same as conventional Java threads except for how they are scheduled. Event handlers encapsulate a bit of work that is done every time some event occurs. Events are referred to as asynchronous because they generally occur independent of program flow. Thus, a timed event is considered to be an asynchronous event, but scheduled periodically. Event handling provides a less resource intensive means of writing control applications because the underlying thread mechanism can be shared between event handlers. Deadline analysis is also somewhat simpler because the end of the work to be done is well bounded. Event handling is ideal for periodic tasks and responding to external impulses. The specification provides both paradigms.

Though realtime is necessary for many control tasks, it is not sufficient. A significant part of the RTSJ API addresses communication with the outside world through devices and signals. This makes it possible to write control applications without resorting to JNI, thereby maintaining the integrity and safety that Java offers.

Since not all applications need all aspects of the specification, there are now modules to suite the major application scenarios. This should make it easier for conventional JVM providers to include basic specification facilities without negatively impacting their core application domains, but still be compatible with hard realtime implementations. The goal is to make the transition between conventional JVMs and realtime JVMs easier.

1.1 Guiding Principles

Providing a coherent semantics and set of programming interfaces requires some guiding principles around which to organize the RTSJ. These principles delimit the scope of the RTSJ and its compatibility requirements with conventional Java.

1.1.1 Applicability to Particular Java Environments

The RTSJ shall not include specifications that restrict its use to a particular Java environment, such as a particular versions of the Java Development Kit, an Embedded

Java Application Environment, or a Java Edition, beyond the natural development of the Java language.

1.1.2 Backward Compatibility

The RTSJ shall not prevent existing, properly written, conventional Java programs from executing on implementations of the RTSJ.

1.1.3 Write Once, Run Anywhere

The RTSJ should recognize the importance of “Write Once, Run Anywhere”, but it should also recognize the difficulty of achieving WORA for realtime programs and not attempt to increase or maintain binary portability at the expense of predictability. Hence, the goal should be “Write Once Carefully, Run Anywhere Conditionally”.

1.1.4 Current Practice vs. Advanced Features

The RTSJ should address current realtime system practice as well as allow future implementations to include advanced features.

1.1.5 Predictable Execution

The RTSJ shall hold predictable execution as first priority in all trade-offs; this may sometimes be at the expense of typical general-purpose computing performance measures.

1.1.6 No Syntactic Extension

In order to facilitate the job of tool developers, and thus to increase the likelihood of timely implementations, the RTSJ shall not introduce new keywords or make other syntactic extensions to the Java language.

1.1.7 Allow Variation in Implementation Decisions

Implementations of the RTSJ may vary in a number of implementation decisions, such as the use of efficient or inefficient algorithms, trade-offs between time and space efficiency, inclusion of scheduling algorithms not required in the minimum implementation, and variation in code path length for the execution of byte codes. The RTSJ should not mandate algorithms or specific time constants for such, but require that the semantics of the implementation be met and where necessary put

limits on execution time complexity. The RTSJ offers implementers the flexibility to create implementations suited to meet the requirements of their customers.

1.1.8 Interoperability

It should be possible to implement all aspects of the RTSJ on a conventional JVM with the exception that realtime response and pointer assignment rules would not necessarily be guaranteed. This should ease the transition between conventional and realtime programming and aid functional testing on a conventional JVM. The API should support modules for this as well.

1.2 Areas of Enhancement

Each guiding principle has had a direct effect on the development of the specification. There are eight aspects of these refinements and additions in the specification. Their enumeration should aid the understanding of the rest of the specification.

1.2.1 Thread Scheduling and Dispatching

Portability dictates the specification of at least one standard realtime scheduler, but in light of the significant diversity in scheduling and dispatching models and the recognition that each model has wide applicability in the diverse realtime systems industry, the specification provides an underlying scheduling infrastructure that can be extended to use other scheduling algorithms for scheduling realtime Java threads and event handlers.

To accommodate current practice, the RTSJ shall require a base scheduler in all implementations. The required base scheduler will be familiar to realtime system programmers. It is a priority preemptive scheduler with priorities above the conventional Java priorities (1–10).

The specification is constructed to allow implementations to provide unanticipated scheduling algorithms. Implementations will enable the programmatic assignment of parameters appropriate for the underlying scheduling mechanism as well as provide any necessary methods for the creation, management and termination of realtime Java threads. In the current specification, any other thread, scheduling, and dispatching mechanism may be bound to an implementation; however, there should be enough flexibility in the thread scheduling framework to enable future versions of the specification to build on this release.

1.2.2 Memory Management

Automatic memory management is a particularly important feature of the Java programming environment. The specification enables, as far as possible, the job of memory management to be implemented automatically by the underlying system and not intrude on the programming task. Many automatic memory management algorithms, also known as garbage collection (GC), exist, and many of those apply to certain classes of realtime programming styles and systems. In an attempt to accommodate a diverse set of GC algorithms, the specification defines a memory allocation and reclamation paradigm that

- is independent of any particular GC algorithm,
- requires the VM to precisely characterize its GC algorithm's effect on the preemption of realtime Java tasks, and
- enables the allocation and reclamation of objects outside of any interference by any GC algorithm.

1.2.3 Synchronization and Resource Sharing

Logic often requires serial access to resources, and realtime systems introduce an additional complexity: the need to minimize priority inversion and hence the excessive delay of more critical tasks. The least intrusive specification for enabling realtime safe synchronization is to require that implementations of the Java keyword `synchronized` implement one or more algorithms that prevent priority inversion among realtime Java tasks that share the serialized resource. In addition, the specification provides other data passing mechanisms to minimize the need for synchronization.

1.2.4 Asynchronous Event Handling

Realtime systems typically interact closely with the real world. With respect to the execution of logic, the real world is asynchronous; therefore, the specification includes efficient mechanisms for programming disciplines that would accommodate this inherent asynchrony. The RTSJ has a general mechanism for asynchronous event handling. This specification provides classes that represent things that can happen and logic that executes when those things happen. The execution of the logic is scheduled and dispatched by the RTSJ runtime.

1.2.5 Task Interruption

Sometimes, the real world changes so drastically (and asynchronously) that the current point of logic execution should be immediately, efficiently, and safely ended and control transferred to another point of execution. The RTSJ provides a mechanism

which extends Java's interrupt and exception handling mechanisms to enable applications to programmatically change the locus of control of another Java task. This mechanism may restrict this asynchronous transfer of control to logic specifically written with the assumption that its locus of control may asynchronously change. Due to the inherent susceptibility to deadlock, the `Thread.stop` method cannot be used for this.

1.2.6 Raw Memory Access

Accessing device memory is not in and of itself a realtime issue, many realtime systems require it for providing realtime control of a system. This requires an API providing programmers with byte-level access to physical device registers, whether in main memory or in some I/O space. This API must be as efficient as possible, since such access is often under tight time constraints.

1.2.7 Physical Memory Access

Some systems provide memory areas that differ in important aspects, such as time to read or write data and its persistence. Being able to take advantage of these areas can have an impact on performance. This specification enables their efficient use.

1.2.8 Modularization

Not all applications require all aspects of the specification. In fact, having a core set of the APIs presented is useful for conventional Java programming and aids overall interoperability. To this end, the specification provides a core set of APIs and a few optional modules as well as semantics for use in conventional JVMs that do not offer realtime guarantees. This should enable implementations to be optimized for particular use cases and enable conventional Java environments to be used to help develop code that can be more easily shared between realtime and conventional systems.

Chapter 2

Overview

The RTSJ comprises several areas of extended semantics. These areas are discussed in approximate order of their relevance to realtime programming. The semantics and mechanisms of each of threads and scheduling, synchronization, asynchrony, clocks and timers, memory management, device access and raw memory, system options, and exceptions are all crucial to the acceptance of the RTSJ as a viable realtime development platform. Further details, exact requirements, class documentation, and rationale for these extensions are given in subsequent chapters.

2.1 Threads and Scheduling

One of the concerns of realtime programming is to ensure the timely and predictable execution of sequences of machine instructions. Various scheduling schemes name these sequences of instructions differently, for example, thread, task, module, or block. In Java, this computation is executed in the context of a thread. Since Java threads were designed for fair execution¹ rather than predictable execution, the RTSJ introduces the concept of a *schedulable*. These are the objects managed by the base scheduler: `RealtimeThread` and its subclasses and `AsyncBaseEventHandler` and its subclasses. `RealtimeThread` is a specialization of Java's `Thread`.

Timely execution of schedulables means that the programmer can determine, by analysis of the program, testing the program on particular implementations, or both, whether particular threads will always complete execution before a given timeliness constraint. This is the essence of realtime programming: the addition of temporal constraints to the correctness conditions for computation. For example, for a program to compute the sum of two numbers, it may no longer be acceptable to

¹Actually, neither the Java Virtual Machine Specification[6] nor the Java Language Specification[5] defines how Java threads should be scheduled, but most implementations, including the reference implementations, use some sort of fair scheduling.

compute only the correct arithmetic answer but the answer must be computed within a particular time interval. Typically, temporal constraints are deadlines expressed in either relative or absolute time.

The term *scheduling* (or *scheduling algorithm*) refers to the production of a sequence (or ordering) for the execution of a set of schedulables (a *schedule*). This schedule attempts to optimize a particular metric (a metric that measures how well the system is meeting the temporal constraints). A *feasibility analysis* determines if a schedule has an acceptable value for the metric. For example in hard realtime systems, the typical metric is “number of missed deadlines” and the only acceptable value for that metric is zero. So called soft realtime systems use other metrics (such as mean tardiness) and may accept various values for the metric in use.

Many systems, including most conventional Java implementations, use thread priority to guide the determination of a schedule. Priority is typically an integer associated with a thread; these integers convey to the system the order in which the threads should execute. The generalization of the concept of priority is *execution eligibility*. The term *dispatching* refers to that portion of the system which selects the thread with the highest execution eligibility from the pool of threads that are ready to run.

In current realtime system practice, the assignment of priorities is typically under programmer control as opposed to under system control. As a base scheduler for realtime tasks, the RTSJ provides preemptive priority-based first-in-first-out (FIFO) scheduler, which also leaves the assignment of priorities to programmer control. Most realtime operation systems (RTOS) are also based on priority preemptive FIFO scheduling.

The RTSJ defines a number of classes with names of the format `<string>Parameters` such as `ReleaseParameters`, which provide parameters for resource management. An instance of one of these parameter classes holds a particular resource-demand characteristic for one or more schedulables. For example, the `PriorityParameters` subclass of `SchedulingParameters` contains the execution eligibility metric of the base scheduler, i.e., a priority. At some time (construction-time or later when the parameters are replaced using setter methods), instances of parameter classes are bound to a schedulable. The schedulable then assumes the characteristics of the values in the parameter object. For example, a `PriorityParameters` instance with its priority set to the value representing the highest priority available on a system is bound to a schedulable, then that schedulable will assume the characteristic that it will execute whenever it is ready in preference to all other schedulables (except, of course, those also with the same priority).

The RTSJ provides implementers with the flexibility to install arbitrary scheduling algorithms in an implementation of the specification. This is to support the widely varying requirements of the realtime systems industry with respect to schedul-

ing. Use of the Java platform may help produce code written once but able to be executed on many different computing platforms. The RTSJ contributes to this goal, but the rigors of realtime systems detract from it. The RTSJ's rigorous specification of the required priority scheduler is critical for portability of time-critical code, but the RTSJ permits and supports platform-specific schedulers which are not necessarily portable.

2.2 Synchronization

If the computation in each thread were independent of the computation in all other threads, scheduling alone would be enough to ensure timeliness; however, this is usually not the case. Threads often need to communicate with one another or share data. Resources must be shared as well. Two threads cannot read different data from the disk at the same time nor write data to a disk at the same time. They cannot send a message to another machine at the same time. They cannot update the same in-memory data at the same time. One thread may have to wait for another thread to get the data it needs. Just as in a normal system, synchronization is required. In a realtime system, this synchronization must not prevent other threads from completing their tasks on time.

2.2.1 Priority Inversion

The additional concern for synchronization in a realtime system, as opposed to a conventional system, is that blocking can cause the wrong thread to run first. A high priority thread can be blocked by a low priority thread that is vying for the same resource. A priority queue can be used to ensure that a highest priority thread goes first, when more than one thread is waiting to enter a synchronized block, but this is not always sufficient.

Consider a single processor system with three threads, t_1 , t_2 , and t_3 , where t_1 has the highest priority and t_3 has the lowest priority. It is possible that t_2 can prevent t_1 from running by preempting t_3 . This is called priority inversion. It occurs when t_1 is blocked by attempting to acquire a lock that is held by thread t_3 and t_3 is preempted by t_2 . When t_2 does run, it may prevent t_3 from running indefinitely, thereby keeping t_1 blocked past its deadline.

What is needed is a mechanism to ensure that, while t_1 is waiting on a resource in use by t_3 , thread t_3 runs before all threads with a priority less than that of t_1 .

2.2.2 Priority Inversion Avoidance

Two of the most common mechanisms for avoiding priority inversion are priority inheritance and priority ceiling emulation (a.k.a. highest locker protocol). Both of these boost the priority of a thread holding the lock in order to prevent a noncontending thread from transitively blocking a higher priority thread which is waiting for the same lock. The difference is how high the priority is raised and when. Both take effect when a thread is in a **synchronized** section of code.

The first is the default behavior for **synchronized** blocks and methods. It applies to all code running within the implementation, not just to **schedulables**. The priority inheritance protocol is a well-known algorithm in the realtime scheduling literature and it has the following effect. If thread t_1 attempts to acquire a lock that is held by a lower-priority thread t_3 , then t_3 's priority is raised to that of t_1 as long as t_3 holds the lock (and recursively if t_3 is itself waiting to acquire a lock held by an even lower-priority thread).

The specification also provides a mechanism by which the programmer can override the default system-wide policy, or control the policy to be used for a particular monitor, provided that policy is supported by the implementation. The second policy, priority ceiling emulation protocol, can be set using this mechanism. It is also a well-known algorithm in the literature. The following three points provide a somewhat simplified description of its effect.

- A monitor is given a “priority ceiling” when it is created; the programmer should choose at least the highest priority of any thread that could attempt to enter the monitor.
- As soon as a thread enters synchronized code, its (active) priority is raised to the monitor's ceiling priority. If, through programming error, a thread has a higher base priority than the ceiling of the monitor it is attempting to enter, then an exception is thrown.
- On leaving the monitor, the thread has its active priority reset. In simple cases it will set be to the thread's previous active priority, but under some circumstances (e.g. a dynamic change to the thread's base priority while it was in the monitor) a different value is possible.

In addition, threads and asynchronous event handlers waiting to acquire a resource must be released from highest to lowest priority (in priority order). This applies to processors as well as to synchronized blocks. If schedulables with the same priority are possible under the active scheduling policy, such schedulables are awakened in FIFO order. This is exemplified in the following scenarios.

- Threads waiting to enter synchronized blocks are granted access to the synchronized block in priority order.
- A blocked thread that becomes ready to run is given access to a processor in priority order.

- A thread whose priority is explicitly set by itself or another thread is given access to a processor in priority order.
- A thread that performs a yield will be given access to the processor after waiting for threads of the same priority to be given a processor.
- Threads that are preempted in favor of a thread with higher priority may be given access to a processor at any time as determined by a particular implementation. The implementation is required to provide documentation stating exactly the algorithm used for granting such access.

In any case, there needs to be a fixed upper bound on the time required to enter a synchronized block for an unlocked monitor.

2.2.3 Execution Eligibility

Since an implementation of the RTSJ may provide schedulers other than priority-based schedulers, the notion of priority can be generalized to execution eligibility. Execution eligibility defines a partial ordering over all tasks for determining which task should run before which other tasks. Execution eligibility may be determined dynamically. For example, earliest deadline first (EDF) scheduling determines execution eligibility ordering by the order of the next deadlines for each of its tasks. The notion of priority, as described above, can be generalized to execution eligibility to integrate other schedulers into an RTSJ implementation.

2.2.4 Wait-Free Queues

While the RTSJ requires that the execution of schedulables which do not access the heap must not be delayed by garbage collection on behalf of lower-priority schedulables, an application can cause such a schedulable to wait for garbage collection by synchronizing using an object shared with a heap-using thread or schedulable. The RTSJ provides wait-free queue classes to provide protected, non-blocking, shared access to objects accessed by both regular Java threads and schedulables, which do not access the heap.

2.3 Asynchrony

Since a realtime system must be able to react to the outside world, the system needs to be able to change its execution flow asynchronously to the current execution. All external signals, whether interrupts, messages, or timed events, are asynchronous with respect to ongoing computation. This means that computation must be both startable and stoppable based on external stimuli.

2.3.1 Asynchronous Events

Asynchronous events provide a means of starting computation based on external stimuli. The asynchronous event facility is based on two classes: `AsyncBaseEvent` and `AsyncBaseEventHandler`. An `AsyncBaseEvent` object represents something that can happen, like a POSIX signal, a hardware interrupt, or a computed event like an airplane entering a specified region. When one of these events occurs, which is indicated by the `fire()` method being called, the associated instances of `AsyncBaseEventHandler` are scheduled and the `handleAsyncEvent()` methods are invoked, thus the required logic is performed. Also, methods on `AsyncBaseEvent` are provided to manage the set of instances of `AsyncBaseEventHandler` associated with the instance of `AsyncBaseEvent`.

An instance of an `AsyncBaseEventHandler` can be thought of as something similar to a thread. When an event fires, the associated handlers are scheduled and the `handleAsyncEvent()` methods are invoked. What distinguishes an `AsyncBaseEventHandler` from a simple `Runnable` is that an `AsyncBaseEventHandler` has associated instances of `ReleaseParameters`, `SchedulingParameters` and `MemoryParameters` that control the actual execution of the handler once the associated `AsyncBaseEvent` is fired. When an event is fired, the handlers are executed asynchronously, scheduled according to the associated `ReleaseParameters` and `SchedulingParameters` objects, in a manner that looks like the handler has just been assigned to its own thread. It is intended that the system can cope well with situations where there are large numbers of instances of `AsyncBaseEvent` and `AsyncBaseEventHandler` (tens of thousands), since the number of fired (in progress) handlers is expected to be much smaller.

There are specialized forms of `AsyncBaseEvent`: `AsyncEvent`, `AsyncLongEvent`, and `AsyncObjectEvent` for events that are stateless, carry a `long` payload, and carry an `Object` payload, respectively. They are matched by specialized forms of `AsyncBaseEventHandler`: `AsyncEventHandler`, `AsyncLongEventHandler`, and `AsyncObjectEventHandler`. Most external events are stateless, but sometimes it is helpful to be able to receive some information about the event or pass some data with the event. The `Long` and `Object` variants enable this and the `POSIXRealtimeSignal` takes advantage of it.

Another specialized form of an `AsyncEvent` is the `Timer` class, which represents an event whose occurrence is driven by time. There are two forms of `Timers`: the `OneShotTimer` and the `PeriodicTimer`. Instances of `OneShotTimer` fire once, at the specified time. Periodic timers fire initially at the specified time, and then periodically according to a specified interval.

Timers are driven by `Clock` objects. There is a special `Clock` object, `Clock.getRealtimeClock()`, that represents the realtime clock. The `Clock` class may be extended to represent other clocks, which the underlying system might make

available (such as an execution-time clock of some granularity).

2.3.2 Asynchronous Transfer of Control

Many event-driven computer systems that tightly interact with external physical systems (e.g., humans, machines, control processes, etc.) may require mode changes in their computational behavior as a result of significant changes in the non-computer real-world system. It simplifies the architecture of a system when a task can be programmatically terminated when an external physical system change causes its computation to be superfluous. Without this facility, a thread or set of threads have to be coded so that their computational behavior anticipates all of the possible transitions among possible states of the external system. When the external system makes a state transition, the changes in computation behavior can be managed by an oracle that terminates a set of threads required for the old state of the external system, and invokes a new set of threads appropriate for the new state of the external system. Since the possible state transitions of the external system are encoded in only the oracle and not in each thread, the overall system design is simpler.

There is a second requirement for a mechanism to terminate some computation, where a potentially unbounded computation needs to be done in a bounded period of time. In this case, if that computation can be executed with an algorithm that is iterative, and produces successively refined results, the system could abandon the computation early and still have usable results. The RTSJ supports aborting a computation by signalling from another thread, or the passage of time, with a feature termed Asynchronous Transfer of Control (ATC).

An example of the second case is processing compressed video for a human controller. The system knows that a new frame must be produced at a constant update frequency. The cost of each iteration is highly variable and the minimum required latency to terminate the computation and receive the last consistent result is much less than the mean iteration cost and bound. Therefore, using ATC for interrupting a computation to capture an intermediate result at the expiration of a known time bound is a convenient programming style. Of course, there are other kinds of programming tasks that may also benefit from ATC.

2.3.3 Principles

The RTSJ's approach to ATC uses asynchronous interruptions and exceptions, and is based on several guiding principles covering methodology, expressiveness, semantics, and pragmatic concerns.

2.3.3.1 Methodological Principles

- A method must explicitly indicate its susceptibility to ATC, i.e., it is asynchronously interruptible. Since legacy code or library methods might have been written assuming no ATC, by default ATC must be turned off (more precisely, must be deferred as long as control is in such code).
- Even if a method allows ATC, some code sections must be executed to completion and thus ATC is deferred in such sections. These ATC-deferred sections are synchronized methods, static initializers, and synchronized statements.
- Code that responds to an ATC does not return to the point in the schedulable where the ATC was triggered; that is, an ATC is an unconditional transfer of control. Resumptive semantics, which returns control from the handler to the point of interruption, are not needed since they can be achieved through other mechanisms (in particular, an `AsyncEventHandler`).

2.3.3.2 Expressibility Principles

- A mechanism is needed through which an ATC can be explicitly triggered in a target schedulable. This triggering may be direct (from a source thread or schedulable) or indirect (through an asynchronously interrupted exception).
- It must be possible to trigger an ATC based on any asynchronous event including an external happening or an explicit event firing from another thread or schedulable. In particular, it must be possible to base an ATC on a timer going off.
- Through ATC it must be possible to abort a realtime thread but in a manner that does not carry the dangers of the `Thread` class's `stop()` and `destroy()` methods.

2.3.3.3 Semantic Principles

- If ATC is modeled by exception handling, there must be some way to ensure that an asynchronous exception is only caught by the intended handler and not, for example, by an all-purpose handler that happens to be on the propagation path.
- Nested ATCs must work properly. For example, consider two, nested ATC-based timers and assume that the outer timer has a shorter time-out than the nested, inner timer. If the outer timer times out while control is in the nested code of the inner timer, then the nested code must be aborted (as soon as it is outside an ATC-deferred section), and control must then transfer to the appropriate `catch` clause for the outer timer. An implementation that either handles the outer time-out in the nested code, or that waits for the longer (nested) timer, is incorrect.

2.3.3.4 Pragmatic Principles

- There should be straightforward idioms for common cases such as timer handlers and realtime thread termination.
- If code with a time-out completes before the timer's expiration, the timer needs to be automatically stopped and its resources returned to the system.

2.3.4 Asynchronous Realtime Thread Termination

A special case of stopping a particular computation is stopping a thread. Earlier versions of the Java language supplied mechanisms for achieving these effects: in particular the methods `stop()` and `destroy()` in class `Thread`. However, since `stop()` could leave shared objects in an inconsistent state, `stop()` has been deprecated. The use of `destroy()` can lead to deadlock (if a thread is destroyed while it is holding a lock) and although it was not deprecated until version 1.5 of the Java specification, its usage has long been discouraged. A goal of the RTSJ was to meet the requirements of asynchronous thread termination without introducing the dangers of the `stop()` or `destroy()` methods.

The RTSJ accommodates safe asynchronous realtime thread termination through a combination of the asynchronous event handling and the asynchronous transfer of control mechanisms. To create such a set of realtime threads consider the following steps:

- make all of the application methods of the realtime thread asynchronously interruptible;
- create an oracle which monitors the external world by setting up an asynchronous event with a number of asynchronous event handlers, which is fired when an appropriate mode change;
- have the handlers call `interrupt()` on each of the realtime threads affected by the change; then
- after the handlers call `interrupt()`, have them create a new set of realtime threads appropriate to the current state of the external world.

The effect of the event is to cause each interruptible method to abort abnormally by transferring control to the appropriate catch clause. Ultimately the `run()` method of the realtime thread will complete normally.

This idiom provides a quick (if coded to be so) but orderly clean up and termination of the realtime thread. Note that the oracle can comprise as many or as few asynchronous event handlers as appropriate.

2.4 Clocks, Time, and Timers

Realtime systems require a high resolution notion of time. Both very small units and very long periods of time must be uniformly representable, a range that is not even representable with a `long` value. Furthermore, a time can represent an absolute value, usually represented as some absolute fixed point in time plus an offset, or it can represent an interval of time. The time classes defined in Chapter 9 support a `long` worth of seconds and another integer for nanoseconds.

2.5 Memory Management

The Java language is designed around automatic memory management, in particular garbage collection. Unfortunately, though garbage collection is a functional safety and security feature, conventional garbage collectors interrupt the normal flow of control in a program. Therefore, garbage-collected memory heaps had been considered an obstacle to realtime programming due to the potential for unpredictable latencies introduced by the garbage collector. Though convention collectors still have these drawbacks, there are now realtime collectors that can be used for hard realtime application. Still, the RTSJ provides an alternative to garbage collection for systems which require it, either because they do not have a garbage collector or deterministic garbage collector, or require heap partitioning for some other reason. Extensions to the memory model, which support memory management in a manner that does not interfere with the ability of realtime code to provide deterministic behavior, are provided to support these alternatives. This goal is accomplished by providing memory areas for the allocation of objects outside of the garbage-collected heap for both short-lived and long-lived objects. In order to provide additional separation between the garbage collector and schedulables which do not require its services, a schedulable can be marked no-heap to indicate that it never accesses the heap.

2.5.1 Memory Areas

The RTSJ introduces the concept of a memory area. A memory area represents an area of memory that may be used for allocating objects. Some memory areas exist outside of the heap and place restrictions on what the system and garbage collector may do with objects allocated within. Objects in some memory areas are never garbage collected; however, the garbage collector must be capable of scanning these memory areas for references to any object within the heap to preserve the integrity of the heap.

There are four basic types of memory areas:

- Heap memory represents an area of memory that is the heap. The RTSJ does not change the determinant of lifetime of objects on the heap. The lifetime is still determined by visibility.
- Immortal memory represents an area of memory containing objects that may be referenced without exception or garbage collection delay by any schedulable, specifically including no-heap realtime threads and no-heap asynchronous event handlers.
- Scoped memory provides a mechanism for managing objects that have a lifetime defined by their scope. It is akin to, but more general than, allocating objects on the thread stack.
- Physical memory allows objects to be created within specific physical memory regions that have particular important characteristics, such as memory that has substantially faster access.

2.5.2 Heap Memory

Heap memory is the memory area used by Java by default. It is garbage collected and the access time to objects in this area are not guaranteed unless the implementation supports realtime garbage collection. The RTSJ, as with conventional Java, supports only one Heap in a system. Multiple heaps are only practical in one of two configurations: the heaps are completely independent of one another or there are subsidiary heaps from which a program may not store references in the main heap. In other words, the subsidiary heaps can reference the main heap but not vice versa. Currently, the RTSJ does not address these cases.

2.5.3 Immortal Memory

`ImmortalMemory` is a memory resource shared among all schedulable objects and threads in an application. Objects allocated in `ImmortalMemory` are always available to non-heap threads and asynchronous event handlers without the possibility of a delay for garbage collection.

2.5.4 Scoped Memory

The RTSJ introduces the concept of scoped memory. A memory scope is used to give bounds to the lifetime of any objects allocated within it. When a scope is entered, every use of `new` causes the memory to be allocated from the active memory scope. A scope may be entered explicitly, or it can be attached to a schedulable which will effectively enter the scope before it executes the object's `run()` method.

The contents of a scoped memory are discarded when no object in the scope can be accessed. This is done by a technique similar to reference counting the scope.

A conforming implementation might maintain a count of the number of external references to each memory area. The reference count for a **ScopedMemory** area would be increased by entering a new scope through the **enter()** method of **MemoryArea**, by the creation of a schedulable using the particular **ScopedMemory** area, or by the opening of an inner scope. The reference count for a **ScopedMemory** area would be decreased when returning from the **enter()** method, when the schedulable using the **ScopedMemory** terminates, or when an inner scope returns from its **enter()** method. When the count drops to zero, the finalize method for each object in the memory would be executed to completion. Reuse of the scope is blocked until finalization is complete.

Scopes may be nested. When a nested scope is entered, all subsequent allocations are taken from the memory associated with the new scope. When the nested scope is exited, the previous scope is restored and subsequent allocations are again taken from that scope.

Because of the lifetimes of scoped objects, it is necessary to limit the references to scoped objects, by means of a restricted set of assignment rules. A reference to a scoped object cannot be assigned to a variable from an outer scope, or to a field of an object in either the heap or the immortal area. A reference to a scoped object may only be assigned into the same scope or into an inner scope. The virtual machine must detect illegal assignment attempts and must throw an appropriate exception when they occur.

The flexibility provided in choice of scoped memory types allows the application to use a memory area that has characteristics that are appropriate to a particular syntactically defined region of the code.

2.5.5 Physical Memory Areas

In many cases, systems needing the predictable execution of the RTSJ will also need to access various kinds of memory at particular addresses for performance or other reasons. Consider a system in which very fast static RAM was programmatically available. A design that could optimize performance might wish to place various frequently used Java objects in the fast static RAM. The **PhysicalMemoryRegion** and **PhysicalMemoryFactory** classes provide the programmer this flexibility. The programmer would construct a physical memory object on the memory addresses occupied by the fast RAM.

2.5.6 Budgeted Allocation

The RTSJ also provides limited support for providing memory allocation budgets for schedulables using memory areas. Maximum memory area consumption and

maximum allocation rates for individual schedulable objects may be specified when they are created.

2.6 Device Access and Raw Memory

The RTSJ defines classes for programmers wishing to directly access physical memory from code written in the Java language. The `RawMemory<Size>` types, where `<Size>` is one of `Byte`, `Short`, `Long`, `Float`, or `Double`, define methods that enable the programmer to construct an object that represents a vector of consecutive positions in memory where the `Size` represents a primitive numerical data type, i.e., byte, short, int, long, float, and double respectively. Access to the physical memory is then accomplished through `get<Size>()` and `set<Size>()` methods of that object. No semantics other than the `set<Size>()` and `get<Size>()` methods are implied. On the other hand, the `PhysicalMemoryRegion` and `PhysicalMemoryFactory` classes enable programmers to construct an object that represents a range of physical memory addresses. When this object is used as a `MemoryArea` other objects can be constructed in the physical memory using the new keyword as appropriate. Factories can be used to create the desired type of both physical and raw memory.

2.6.1 Raw Memory Access

An instance of `RawMemoryType` models a range of physical memory locations as a fixed sequence of elements of a given size. The elements correspond to Java primitive types. For objects that access more than a single physical address, elements can be accessed through offsets from the base, where the offset is measured in multiples of the element size, not necessarily the byte offset in memory.

The `RawMemoryType` interface enables a realtime program to implement device drivers, memory-mapped registers, I/O space mapped registers, flash memory, battery-backed RAM, and similar low-level hardware.

A raw memory area cannot contain references to Java objects. Such a capability would be unsafe (since it could be used to defeat Java's type checking) and error prone (since it is sensitive to the specific representational choices made by the Java compiler).

2.7 System Options

POSIX defines some convenient interfaces for interacting with the system. These interactions include catching keyboard interrupts, user-to-process signaling, and interprocess signaling. Many realtime operating systems support this POSIX signal

interface. For this reason, the RTSJ provides a POSIX signal interface. Though many of the features POSIX signals provide are also available on most other operating systems, the specification does not require the POSIX signal interface to be emulated on these other platforms. Thus they are optional in the sense that they are only required on systems that directly support POSIX signals.

2.8 Exceptions

Aside from several new exceptions, the RTSJ provides a new interface for using exceptions without creating ephemeral objects and some new treatment of exceptions surrounding asynchronous transfer of control.

Using exceptions is resource intensive, since a new exception is allocated for each throw. This is particularly a problem for scoped memory, since scopes may need to be sized much larger than otherwise necessary to hold exceptions and their stack traces. Additionally, the information they contain cannot be propagated beyond the scope in which they are allocated. To better support scoped, immortal, and physical memory, a new class of throwable has been included: `PreallocatedThrowable`. Exceptions and Errors which implement this interface are not thrown in the usual manner, but with a style that does not require memory to be allocated at all.

Asynchronous transfer of control can cause the exception that triggered it to be propagated even when it is caught but the underlying interrupt is not cleared. The system rethrows the exception once the catch is finished. This is necessary since the exception hierarchy is poorly designed. There is a base class neither for all checked exceptions nor for all errors. There is no common base class for checked exceptions, so application code often contains a catch for `Exception` when only checked exceptions need to be caught. Even the JVM specification wording is awkward on this point, where a checked exception is an exception that is not a subclass of `RuntimeException` and an error is a throwable that is not a subclass of `Exception`.

2.9 Summary

The RTSJ refines the semantics of threads, scheduling, synchronization, memory management, and exceptions and adds features to support realtime threads, realtime scheduling, configuring synchronization, asynchrony, representing time, clocks and timers, additional methods for memory management, device access and raw memory, system options. These features and semantic refinements to the Java language and virtual machine have been outlined above, but the description does not constitute a definition for them. In other words, it is not normative. The normative chapters follow.

Chapter 3

Requirements and Conventions

This specification is a contract between the specification implementer and the user who writes a program to run on an implementation. To be able to support both implementation and use, many chapters provide additional rationale to help both the implementer and the user understand the intention behind the normative text. The remainder of this specification, including this chapter, is normative, except for the introductory text in each chapter and the sections named Rationale.

3.1 Base Requirements

The base requirements of this specification are as follows.

- Except as specifically required by this specification, any implementation shall fully conform to a Java platform configuration.
- Any implementation of this specification shall implement all classes and methods in the base module of this specification.
- Except as noted in this chapter, all classes and methods in an implemented module shall be implemented.
- The `javax.realtime` package shall contain no public or protected classes or methods not included in this specification.
- A realtime JVM implementation shall not be implemented in a way that permits unbounded priority inversion in any scheduling interaction it implements.
- Subject to the usual assumptions, the methods in `javax.realtime` can safely be used concurrently by multiple threads unless otherwise documented.
- Static final values, as found in `AperiodicParameters`, `SporadicParameters`, `RealtimeSystem`, and `PriorityScheduler`, shall be implemented such that their values cannot be resolved by a conformant Java compiler (Java source to byte code).

Many aspects of this specification set a minimum requirement, but permit the implementation latitude in its implementation. For instance, the required priority scheduler requires at least 28 consecutively numbered realtime priorities. It does not, however, specify the numeric values of the maximum and minimum realtime priorities. Implementations are encouraged to offer as many realtime priority levels immediately above the conventional Java priorities as they can support.

Except where otherwise specified, when this specification requires object creation the object is created in the current allocation context.

3.2 Modules

The original RTSJ specification was conceived, with the exception of some optional features, as a monolith specification. This has inhibited the adoption of the RTSJ beyond the hard realtime community, because some of the features were considered to have an overly negative impact on overall JVM performance. Version 2.0 addresses this by breaking the specification into modules.

Modules provide a means of grouping like functionality together in a way that promotes maximal adoption for various implementation classes. A conventional JVM could simply implement the Base Module, without providing any realtime guarantees at all, to provide programmers with the benefits of features such as asynchronous event programming as an alternative to conventional threading. A hard realtime implementation could implement all modules to provide the maximal flexibility and functionality to the realtime programmer. Both would benefit from easier migration of code to realtime systems.

Every RTSJ implementation shall provide the Base Module functionality, but all other modules are optional. The optional modules are the Device Module and the Alternative Memory Areas module. In addition, there are a couple of optional features as well. This give the implementation some choice over which modules and features to include and which not.

3.2.1 Base Module

The Base Module adds the concepts of processor affinity, threads with realtime scheduling, and asynchronous event handling. This includes the notion of executing code at a given time interval, providing a much more stable response than using `sleep` in a loop. These features should have no impact on the overall performance of a system that implements them, but enrich the programming modules available to the programmer. The classes and interfaces required in this module are all in package `javax.realtime` and are listed below.

- `AbsoluteTime` (Section 9.4.1.1)

- `ActiveEvent` (Section 8.4.1.1)
- `ActiveEventDispatcher` (Section 8.4.3.1)
- `Affinity` (Section 6.4.2.1)
- `AperiodicParameters` (Section 6.4.2.2)
- `AsyncBaseEvent` (Section 8.4.3.2)
- `AsyncBaseEventHandler` (Section 8.4.3.3)
- `AsyncEvent` (Section 8.4.3.4)
- `AsyncEventHandler` (Section 8.4.3.5)
- `AsyncLongEvent` (Section 8.4.3.6)
- `AsyncLongEventHandler` (Section 8.4.3.7)
- `AsyncObjectEvent` (Section 8.4.3.8)
- `AsyncObjectEventHandler` (Section 8.4.3.9)
- `BoundAsyncEventHandler` (Section 8.4.3.10)
- `BoundAsyncBaseEventHandler` (Section 8.4.1.3)
- `BoundAsyncLongEventHandler` (Section 8.4.3.11)
- `BoundAsyncObjectEventHandler` (Section 8.4.3.12)
- `Clock` (Section 10.4.2.1)
- `ConfigurationParameters` (Section 5.3.2.1)¹ (Section 8.4.3.3)
- `GarbageCollector` (Section 13.3.1.1)
- `HeapMemory` (Section 11.4.2.1)
- `HighResolutionTime` (Section 9.4.1.2)
- `ImmortalMemory` (Section 11.4.2.2)
- `ImportanceParameters` (Section 6.4.2.4)
- `MemoryArea` (Section 11.4.2.3)
- `MemoryAreaVisitor` (Section 11.4.1.1)
- `MonitorControl` (Section 7.4.1.1)
- `OneShotTimer` (Section 10.4.2.2)
- `PeriodicParameters` (Section 6.4.2.5)
- `PeriodicTimer` (Section 10.4.2.3)
- `PhasingPolicy` (Section 5.3.1.1)
- `PriorityCeilingEmulation` (Section 7.4.1.2)
- `PriorityInheritance` (Section 7.4.1.3)
- `PriorityParameters` (Section 6.4.2.6)
- `PriorityScheduler` (Section 6.4.2.7)
- `ProcessingGroup` (Section 6.4.2.8)
- `RealtimeSecurity` (Section 13.3.1.6)
- `RealtimeSystem` (Section 13.3.1.7)
- `RealtimeThread` (Section 5.3.2.2)
- `RelativeTime` (Section 9.4.1.3)

¹The `mayUseHeap` flag is present, but can only be set if the Memory Module is supported.

- `ReleaseParameters` (Section 6.4.2.9)
- `Schedulable` (Section 6.4.1.3)
- `Scheduler` (Section 6.4.2.11)
- `SchedulingParameters` (Section 6.4.2.13)
- `SizeEstimator` (Section 11.4.2.5)
- `SporadicParameters` (Section 6.4.2.14)
- `Timable` (Section 10.4.1.3)
- `TimeDispatcher` (Section 10.4.2.4)
- `Timer` (Section 10.4.2.5)

All throwables defined in the RTSJ are also in the `javax.realtime` package:

- `AlignmentError` (Section 14.3.3.1)
- `ArrivalTimeQueueOverflowException` (Section 14.3.2.1)
- `CeilingViolationException` (Section 14.3.2.2)
- `DeregistrationException` (Section 14.3.2.3)
- `DuplicateFilterException` (Section 15.3.2.1)
- `MemoryAccessError` (Section 14.3.3.4)
- `IllegalAssignmentError` (Section 14.3.3.3)
- `InaccessibleAreaException` (Section 14.3.2.4)
- `LateStartException` (Section 14.3.2.5)
- `MemoryInUseException` (Section 14.3.2.7)
- `MemoryScopeException` (Section 14.3.2.8)
- `MemoryTypeConflictException` (Section 14.3.2.9)
- `MITViolationException` (Section 14.3.2.6)
- `OffsetOutOfBoundsException` (Section 14.3.2.10)
- `ProcessorAffinityException` (Section 14.3.2.11)
- `RegistrationException` (Section 14.3.2.12)
- `ResourceLimitError` (Section 14.3.3.5)
- `ScopedCycleException` (Section 14.3.2.13)
- `SizeOutOfBoundsException` (Section 14.3.2.14)
- `ThrowBoundaryError` (Section 14.3.3.7)
- `UnsupportedPhysicalMemoryException` (Section 14.3.2.16)
- `UnsupportedRawMemoryRegionException` (Section 14.3.2.17)

3.2.2 Device Module

The Device Module provides a low level interface for interacting with the real world. Though realtime control systems need this kind of interaction, other systems can benefit from it as well. Data collection, that is not time critical is a good example. For instance, monitoring the temperature or humidity in a room could be done easily with off-the-self hardware using this module. The classes required in this module are all in the package `javax.realtime.device` and are listed below.

- [Happening](#) (Section 12.4.2.1)
- [HappeningDispatcher](#) (Section 12.4.2.2)
- [InterruptServiceRoutine](#) (Section 12.4.2.3)
- [POSIXRealtimeSignal](#) (Section 13.3.1.2)
- [POSIXRealtimeSignalDispatcher](#) (Section 13.3.1.3)
- [POSIXSignal](#) (Section 13.3.1.4)
- [POSIXSignalDispatcher](#) (Section 13.3.1.5)
- [RawBufferFactory](#) (Section 12.4.2.4)
- [RawMemory](#) (Section 12.4.1.16)
- [RawMemoryFactory](#) (Section 12.4.2.5)
- [RawMemoryRegion](#) (Section 12.4.2.6)
- [RawMemoryRegionFactory](#) (Section 12.4.1.17)
- [RawByte](#) (Section 12.4.1.1)
- [RawByteReader](#) (Section 12.4.1.2)
- [RawByteWriter](#) (Section 12.4.1.3)
- [RawDouble](#) (Section 12.4.1.4)
- [RawDoubleReader](#) (Section 12.4.1.5)
- [RawDoubleWriter](#) (Section 12.4.1.6)
- [RawFloat](#) (Section 12.4.1.7)
- [RawFloatReader](#) (Section 12.4.1.8)
- [RawFloatWriter](#) (Section 12.4.1.9)
- [RawInt](#) (Section 12.4.1.10)
- [RawIntReader](#) (Section 12.4.1.11)
- [RawIntWriter](#) (Section 12.4.1.12)
- [RawLong](#) (Section 12.4.1.13)
- [RawLongReader](#) (Section 12.4.1.14)
- [RawLongWriter](#) (Section 12.4.1.15)
- [RawMemoryFactory](#) (Section 12.4.2.5)
- [RawMemoryRegionFactory](#) (Section 12.4.1.17)
- [RawShort](#) (Section 12.4.1.18)
- [RawShortReader](#) (Section 12.4.1.19)
- [RawShortWriter](#) (Section 12.4.1.20)

3.2.3 Alternative Memory Area Module

The Alternative Memory Areas Module provides an alternative to a single heap with garbage collection model for memory management. Most of the facilities are centered around providing an alternative to garbage collection, but facilities for providing what memory to use for Java objects is also addressed. The classes required in this module are all in package `javax.realtime.memory` and are listed below.

- [LTMemory](#) (Section 15.3.3.2)

- `MemoryParameters` (Section 11.4.2.4)
- `PhysicalMemoryCharacteristic` (Section 11.5.1.1)
- `PhysicalMemoryFactory` (Section 11.5.3.2)
- `PhysicalMemoryRegion` (Section 11.5.3.3)
- `PhysicalMemorySelector` (Section 11.5.3.4)
- `PinnableMemory` (Section 11.5.3.5)
- `ScopedMemory` (Section 15.3.3.11)
- `StackedMemory` (Section 11.5.3.7)
- `VirtualMemoryCharacteristic` (Section 11.5.1.2)
- `WaitFreeReadQueue` (Section 7.4.1.5)
- `WaitFreeWriteQueue` (Section 7.4.1.6)

3.2.4 Optional Features

Even with modules it is difficult to eliminate all optional features. These features are either not easy to implement on all platforms or have the potential to cause a significant performance overhead. Therefore, an application cannot depend on them to be present in every implementation. However, if an optional facility is implemented, the application may rely on it to behave as specified here. Those extensions are illustrated in Table 3.1.

Table 3.1: RTSJ Options

Cost enforcement	Enables the application to control the processor utilization of a schedulable.
Processing Group enforcement	Enables the application to control the processor utilization of a group of schedulables
Processing Group deadline less than period	Enables the application to specify a processing group deadline less than the processing group period
Allocation-rate enforcement on heap allocation	Enables the application to limit the rate at which a schedulable creates objects in the heap.
Interrupt Service Routine	Provides first level interrupt processing in Java.
Asynchronous Transfer of Control (ATC)	Enables schedules to be interrupted asynchronously.

The `ProcessingGroup` class is only functional on systems that support the processing group enforcement option. Cost enforcement, and cost overruns handlers are only functional on systems that support the cost enforcement option. If processing group enforcement is supported, `ProcessingGroup` shall function as specified. If

cost enforcement is supported, cost enforcement, and cost overrun handlers shall function as specified.

In implementations where the processing group deadline less than period is not supported, values passed to the constructor for `ProcessingGroup` and its `setDeadline` method are constrained to be equal to the period. If the option is supported, processing group deadlines less than the period shall be supported and function as specified.

In implementations where heap allocation rate enforcement is supported, it shall be implemented as specified. If heap allocation rate enforcement is not supported, the allocation rate attribute of `MemoryParameters` shall be checked for validity but otherwise ignored by the implementation.

First level interrupt handling can only be supported in certain contexts, such as in kernel space and in a device driver context in user space on systems that support this feature. Normally user space programs cannot handle interrupts directly. The class should be present in every system that implements the device module, but in implementations that do not support first level interrupt handling, the `register` should always throw an `UnsupportedOperationException`.

ATC, if implemented, requires the following classes:

- `Timed` (Section 8.4.2.2)
- `AsynchronouslyInterruptedException` (Section 8.4.2.1)
- `Interruptible` (Section 8.4.1.4)

Extensions to this specification are allowed, but shall not require changes to the `javax.realtime` package tree.

3.2.5 Deprecated Classes

Classes that have been deprecated as of this specification are not part of any module, but may be implemented by a full RTSJ implementation. They comprise the following classes:

- `ImmortalPhysicalMemory` (Section 15.3.3.1)
- `PhysicalMemoryManager` (Section 15.3.3.6)
- `PhysicalMemoryTypeFilter` (Section 15.3.1.1)
- `POSIXSignalHandler` (Section 15.3.3.5)
- `RationalTime` (Section 15.3.3.8)
- `RawMemoryAccess` (Section 15.3.3.9)
- `RawMemoryFloatAccess` (Section 15.3.3.10)
- `VTMemory` (Section 15.3.3.12)
- `VTPhysicalMemory` (Section 15.3.3.13)
- `WaitFreeDequeue` (Section 15.3.3.14)

They are documented fully in Chapter 15.

3.3 Conditionally-Required Facilities

An implementation shall support conditionally-required facilities if the underlying hardware and software permits. This specification includes two conditionally-required facilities:

POSIXSignal	This class shall be implemented on every platform where POSIX signals are supported.
RawMemory	If the system supports address translation, e.g., has an MMU, and implements the Device Module, the implementation shall support the memory mapping features of the raw memory access classes.

3.3.1 Options for Development Platforms

The following semantics are optional for an RTSJ implementation designed and licensed exclusively as a development tool.

- The priority scheduler need not support fixed-priority preemptive scheduling or the priority inversion avoidance algorithms. This does not excuse an implementation from fully supporting the relevant APIs. It only reduces the required behavior of the underlying scheduler to the level of the scheduler in the Java specification extended to at least 28 priorities.
- No semantics constraining timing beyond the requirements of the Java specifications need be supported. Specifically, garbage collection may delay any thread without bound and any delay in delivering asynchronously interrupted exceptions is permissible including never delivering the exception. Note, however, that if any AIE other than the generic AIE is delivered, it shall meet the AIE semantics, and all heap-memory-related semantics other than preemption remain fully in effect. Further, relaxed timing does not imply relaxed sequencing. For instance, semantics for scoped memory shall be fully implemented.
- The RTSJ semantics that alter standard Java method behavior, such as the modified semantics for `Thread.setPriority` and `Thread.interrupt`, are not required for a development tool, but such deviations from the RTSJ shall be documented, and the implementation shall be able to generate a runtime warning each time one of these methods deviates from standard RTSJ behavior.

These relaxed requirements set a floor for RTSJ development system tool implementations. A development tool may choose to implement semantics that are not required.

3.4 Required Documentation

Each implementation of the RTSJ is required to provide documentation for several behaviors.

- If schedulers other than the base priority scheduler are available to applications, the behavior of the scheduler and its interaction with each other scheduler as detailed in the Scheduling chapter shall be documented. The list of classes that constitute schedulable objects for the scheduler, unless that list is the same as the list of schedulables for the base scheduler, shall be included. If there are restrictions on use of the scheduler from a non-heap context, these restrictions shall be documented as well.
- A schedulable that is preempted by a higher-priority schedulable is placed in the queue for its active priority, at a position determined by the implementation. If the preempted schedulable is not placed at the front of the appropriate queue the implementation shall document the algorithm used for such placement. Placement at the front of the queue may be required in a future version of this specification.
- An implementation is required to document the granularity at which the current CPU consumption is updated for cost monitoring and cost enforcement, when the later is implemented.
- The implementation shall fully document the behavior of any subclasses of `GarbageCollector`.
- An implementation that provides any `MonitorControl` subclasses not detailed in this specification shall document their effects, particularly with respect to priority inversion control and which (if any) schedulers fail to support the new policy.
- If on losing “boosted” priority due to a priority inversion avoidance algorithm, the schedulable is not placed at the front of its new queue, the implementation shall document the queuing behavior.
- For any available scheduler other than the base scheduler, an implementation shall document how, if at all, the semantics of synchronization differ from the rules defined for the default `PriorityInheritance` monitor control policy. It shall supply documentation for the behavior of the new scheduler with priority inheritance (and, if it is supported, priority ceiling emulation protocol) equivalent to the semantics for the base priority scheduler found in the Synchronization chapter. If there are restrictions on use of the scheduler from a no-heap context, the documentation shall detail the effect of these restrictions for each RTSJ API.
- The worst-case response interval between firing an `AsyncEvent` because of a bound happening to releasing an associated `AsyncEventHandler` (assuming no higher-priority schedulables are runnable) shall be documented for some

reference architecture.

- The interval between firing an `AsynchronouslyInterruptedException` at an ATC-enabled thread and first delivery of that exception (assuming no higher-priority schedulables are runnable) shall be documented for some reference architecture.
- If cost enforcement is supported, and the implementation assigns the cost of running finalizers for objects in scoped memory to any schedulable other than the one that caused the scope's reference count to drop to zero by leaving the scope, the rules for assigning the cost shall be documented.
- If cost enforcement is supported, and enforcement (blocked-by-cost-overflow) can be delayed beyond the enforcement time granularity, the maximum such delay shall be documented.
- If the implementation of `RealtimeSecurity` is more restrictive than the required implementation, or has run-time configuration options, those features shall be documented.
- For each supported clock, the documentation shall specify whether the resolution is settable, and if it is settable the documentation shall indicate the supported values.
- If an implementation includes any clocks other than the required realtime clock, their documentation shall indicate in what contexts those clocks can be used. If they cannot be used in no-heap context, the documentation shall detail the consequences of passing the clock, or a time that uses the clock to a no-heap schedulable.

3.5 Conventions

Throughout the RTSJ, when we use the word *code*, we mean code written in the Java programming language. When we mention the Java language in the RTSJ, that also refers to the Java programming language. The use of the term *heap* in the RTSJ will refer to the heap used by the runtime of the Java language.

3.6 Definitions

A *thread* is an instance of the `java.lang.Thread` class.

A *realtime thread* is an instance of the `javax.realtime.RealtimeThread` class.

A *Java thread* is a thread that is not a realtime thread.

A *no-heap realtime thread* is an instance of the `javax.realtime.RealtimeThread` class that will not access the heap.

An *event handler* is an instance of the `javax.realtime.AbstractAsyncEventHandler` class.

The term *schedulable* refers to any object that is of type `Schedulable`, and is recognized as a dispatchable entity by the base scheduler. The base scheduler's set of schedulables comprises instances of `RealtimeThread` and `AsyncEventHandler`. Other schedulers may support a different set of schedulables, but this specification only defines the behavior of the base scheduler so the term *schedulable* should be understood as “schedulable by the base scheduler.”

Chapter 4

Conventional Java Classes and Language

Though compatibility with conventional Java, i.e., any Java runtime environments that implement the Java Virtual Machine Specification and the Java Language Specification but not the RTSJ, is the first concern of this specification, there are several cases where being able to meet realtime constraints requires a tightening of the semantics of the virtual machine and some subtle changes to the semantics of two key classes: `java.lang.Thread` and `java.lang.ThreadGroup`. These constraints and changes place additional requirements on scheduling, the memory model, and memory management. Finally, the specification defines a new type of concurrent activity called an asynchronous event handler; hence, the meaning of current thread has a different interpretation than in standard java.

4.1 Scheduling

How threads are scheduled in a realtime system is quite different than what one expects in a conventional Java virtual machine. For compatibility, this means that there must be a domain where conventional Java threads are scheduled in a familiar way and another domain that supports realtime scheduling. This separation is done in part via thread priority.

Threads running with the conventional ten priorities defined in Java should be scheduled as expected. Unfortunately, in order to ease the porting of Java to different environments, the scheduling of conventional Java threads is under specified. This has been resolved to avoid surprising the programmer in practice by providing some sort of fair scheduling for these threads, i.e, scheduling that at least prevents thread starvation, but may also try to balance CPU availability across threads. For threads running in these priorities an implementation of this specification should provide

some notion of fair scheduling between threads with priority between one and ten inclusive.

Realtime threads need a stronger notion of prioritization than conventional Java threads, so this specification requires the implementation of at least a priority-preemptive scheduler with run to completion (or next suspension point) semantics. Priorities above the conventional ten priorities are used for this. Multithreaded code that runs with the priority-preemptive scheduler (or any other realtime scheduler) is more prone to deadlock or starvation than code run with fair scheduling. The changes to `Thread` and `ThreadGroup` are to support this realtime scheduling.

- The semantics of `set` and `get` methods for priority in `Thread` differ for realtime threads.
- The `ThreadGroup` class's behavior differs with respect to realtime threads.
- The behavior of the `ThreadGroup`-related methods in `Thread` differ when they are applied to realtime threads.

Code running at realtime priorities can also block conventional Java threads, possibly indefinitely.

4.1.1 Priority

The methods `setPriority` and `getPriority` in `java.lang.Thread` are `final`. The realtime thread classes are consequently not able to override them and modify their behavior to suit the requirements of the RTSJ scheduler. To bring the `java.lang.Thread` class in line with its realtime subclasses, the semantics of the `getPriority` and `setPriority` methods must be modified.

4.1.1.1 Setting Priority

The `setPriority` method has the following additional requirements.

- Use of `Thread.setPriority()` shall not affect the correctness of the priority inversion avoidance algorithms controlled by `PriorityCeilingEmulation` and `PriorityInheritance`. Changes to the base priority of a realtime thread as a result of invoking `Thread.setPriority()` are governed by semantics from Chapter 7 on *Synchronization*.
- realtime threads may use `setPriority` to apply the expanded range of priorities available to realtime threads. When a realtime thread's priority parameters object is not shared, `setPriority` behaves effectively as if it included the following code snippet:

```

1   PriorityParameters pp = getSchedulingParameters();
2   pp.setPriority(newPriority);

```

- When the realtime thread's priority parameters object is shared with other schedulables, `setPriority` must give the thread an unshared `PriorityParameters` instance allocated in the same memory area as the realtime thread object and containing the new priority value.
- `setPriority` throws `IllegalArgumentException` when the thread is a realtime thread and the new priority is outside the range allowed by the realtime thread's scheduler.
- `setPriority` throws `ClassCastException` when the thread is a realtime thread and its current scheduling parameters object is not an instance of `PriorityParameters`.

4.1.1.2 Getting Priority

The `getPriority` method has the following additional requirements.

- When used on a realtime thread, `getPriority` behaves effectively as if it included the following code snippet:

```
1 (PriorityParameters)t.getSchedulingParameters().getPriority();
```

- When the scheduling parameters are not of type `PriorityParameters`, then a `ClassCastException` is thrown.

All supported monitor control policies must apply to Java threads as well as to all schedulables.

4.1.2 Thread Groups

The RTSJ provides a subclass of `ThreadGroup` called `SchedulingGroup` which provides services similar to `ThreadGroup` for instance of `codeSchedulable`. In an RTSJ implementation, thread groups are rooted at a base `SchedulingGroup` object which may be created in heap or immortal memory. All thread group objects hold references to all their member threads, and subgroups, and a reference to their parent group. Since heap and immortal memory can not hold references to scoped memory, it follows that a thread group can never be allocated in scoped memory. It also follows that no thread allocated in scoped memory may be referenced from any thread group. Schedulable groups are extended to be able to reference threads, schedulables, and other schedulable groups, even when they are in scoped memory. Consequently conventional java threads, schedulables, and schedulable groups are not part of any thread group and will hold a schedule group reference for as their thread group. This also requires that the thread group of the main thread is also a schedulable group, so that schedulables and schedule groups can be created from the main thread.

1. Realtime threads with `null` thread groups are not included in any operation on any thread group. This applies to enumeration and interruption, as well as the deprecated actions `stop`, `resume`, and `suspend`. However, when the current thread is a realtime thread with a `null` thread group:
 - The `Thread.enumerate` class method returns the integer 1, and populates its array argument with the current realtime thread.
 - `Thread.activeCount` returns 1.
 - `Thread.getThreadGroup` returns null in all cases, not only when the thread has terminated.
2. A Java thread (not a realtime thread) that is created from a realtime thread without an explicit thread group and is not assigned a thread group by the security manager inherits the thread group of the realtime thread, when it has one; otherwise an attempt is made to add it to the application root thread group. The constructor shall throw a `SecurityException` when the Java thread is not permitted to use the application root thread group.
3. The thread group of a Java thread created by an asynchronous event handler is assigned as if it was created by a realtime thread without a thread group (as described in 2. above)
4. A thread group cannot be created in scoped memory. The constructor shall throw an `IllegalAssignmentError`.
5. Setting a maximum priority on a thread group, either explicitly or via its parent, has no influence on the realtime threads in that group.
6. Except as specified previously, realtime threads have the same `ThreadGroup` membership rules as the parent `Thread` class.

4.1.3 Current Thread

In Java, the currently executing thread can always be determined by calling the static method `Thread.currentThread()`. In the RTSJ, there are two types of schedulable entities: threads and asynchronous event handlers. The latter may be mapped dynamically by the realtime Java virtual machine onto the underlying thread model. The method `Thread.currentThread()` when called from an unbound asynchronous event handler will return the thread that is being used as the current execution engine for that event handler. The program should not rely on this being constant for the lifetime of the program. It can rely on it being constant for the current *release* of the handler (see 6.2 for the definition of a *release*). It is not recommended that the program perform any operations on this underlying thread as it may have an impact beyond that of the current event handler. This also means that thread local memory cannot be relied on in unbound event handlers, because data saved in one release may not be available in the next release.

4.2 Java Memory Model

Some aspects of the Java Memory Model must be tightened for this specification, in particular with regards to interactions with native code or when using the Device Module. A conforming implementation must ensure that volatile loads and stores, raw memory operations (see 12.3.1), and `RawBufferFactory` fence methods are all ordered in a way that is consistent with respect to native code or hardware devices using platform-native memory coherence protocols to access raw memory or raw byte buffers shared with the virtual machine.

4.3 InterruptedException

The specification extends the use of the `InterruptedException` to support asynchronous transfer of control.

The interruptible methods in the standard libraries (such as `Object.wait`, `Thread.sleep`, and `Thread.join`) have their contract expanded slightly such that they will respond to interruption not only when the interrupt method is invoked on the current thread, but also, for schedulables, when executing within a call to `AIE.doInterruptible` and that AIE is fired. See Chapter 8 on Asynchrony.

4.4 Memory Management

The specification provides for two means of managing memory: garbage collection and special memory areas, which are not collected by the garbage collector. Since memory allocated in Java is always in the heap, or at least appears to be, the initial allocation area is the heap. Furthermore, the allocation area can only be changed either by entering another memory area or by calling a method that explicitly causes allocation in another area. When this alternate memory management module is not present, the conventional java semantics for allocation prevails.

4.4.1 Memory Areas

Using a conventional class in a memory area other than a heap can result in unexpected behavior. This is particularly the case when a method of a class is called in a different area than the object was created, which can lead to exceptions. In general, memory areas other than the heap may become full much faster than expected, because objects that are no longer referenced will not be collected automatically.

A method that allocates an object or takes an object that was created in a different memory area and tries to assign it to a field of its associated object can fail. For example, creating a `List` on the heap and adding to it from a scoped memory

will most likely cause an exception. Although using other memory areas such as scoped memory is useful for helping to improving determinism, its use complicates the logic of application and library code.

On systems that support memory areas other than heap and do not support realtime garbage collection, some global resources must be put in immortal memory. System properties and their `String` values allocated during system initialization shall be allocated in immortal memory. For such a system, class objects should also be stored there. Though this avoids priority inversion with the garbage collector, it can cause higher memory use than expected.

4.4.2 Garbage Collection

Garbage collection is an important safety feature of the Java language and runtime environment. Unfortunately, the garbage collection process can interfere with a realtime program's ability to always meet its timing deadlines. This specification provides two main means of circumventing this problem: using a realtime garbage collector or using the memory area module as an alternative to garbage collection for realtime code. Additionally, an implementation may ignore the problem for an implementation meant as a development system or for systems that choose not to provide realtime guarantees. In any case, an implementation must document what realtime guarantees it gives and which method it uses to do so.

4.4.3 Realtime Garbage Collections

Industrial realtime garbage collectors are available with varying approaches to providing realtime response. Though new collectors will undoubtedly be developed, all current ones use a variant of the mark-and-sweep algorithm. In all cases, the collectors are incremental: realtime response is obtained by limiting how much of a collection cycle is done each time the collector runs. Even on a multicore machine, the garbage collector must be incremental, because it must tolerate changes to the heap during garbage collection. Then CPU use is limited by tying the collector to one or more cores.

4.4.3.1 Thread-Based Collectors

A realtime thread-based collector is an incremental garbage collector that has its own thread of control and runs at intervals. In this case, the garbage collector needs to be scheduled to ensure that it runs often enough and long enough at each interval to recycle discarded objects fast enough to keep up with allocations. There should also be some maximum time after which the garbage collector can be interrupted.

4.4.3.2 Allocation-Based Collectors

A realtime allocation-based garbage collector does not have its own thread of control. Instead, some interval of garbage collection work is done at each allocation. This work is generally a function of the size of the object being allocated. This work becomes part of the execution time of the program. Again, there should be some maximum time after which the garbage collector can be interrupted.

4.4.3.3 Alternatives to Garbage Collection

This specification provide an Alternative Memory Areas Module for managing memory without garbage collection. An implementation of this specification may provide realtime response by requiring applications to use that module instead of providing a realtime garbage collector. This means that all realtime threads would have to run above the priority of the garbage collector and all communication with conventional threads would have to use some nonblocking protocol.

4.4.3.4 Developer Implementation

An implementation that simply provides all the API but no realtime guarantee is also permitted. This is useful as a development environment. Also, many of the APIs are useful event in a conventional Java implementation.

4.5 Summary

The refinements and changes to the semantics of the Java runtime environment and classes shall not affect the functional correctness of Java code written for a conventional Java implementation when running on a Java runtime environment which implements this specification. There may be changes in the relative timing of threads, but these should not violate the conventional Java specifications. The use of some RTSJ features with code written for a conventional Java implementation may, however, be surprising. This is particularly true when using alternate memory areas, asynchronous transfer of control, and thread local memory in conjunction with unbound asynchronous event handlers.

Chapter 5

Realtime Threads

5.1 Overview

Conventional Java provides a thread class for its tasking model. Tasks can be run simultaneously by creating multiple threads, but they do not provide realtime scheduling semantics. For this, the specification provides a realtime thread class, that does. This class provides for the creation of

- realtime threads that have more precise scheduling semantics than `java.lang.Thread`, and
- realtime threads that have no dependency on the heap.

The `RealtimeThread` class extends `java.lang.Thread`. The `ReleaseParameters`, `SchedulingParameters`, and `MemoryParameters` objects that can be passed to the `RealtimeThread` constructor provide the temporal and processor configuration of the thread to be communicated to the *scheduler*. `ProcessingGroup`, a class derived from `ThreadGroup` provides cost enforcement on groups of threads. The `ConfigurationParameters` class defines, amongst other things, the size of Java thread stack; it also indicates whether the `RealtimeThread` is allowed to allocate or even reference objects from the Java heap (and can thus safely execute in preference to the garbage collector). The `PhasingPolicy` class defines the relationship between the threads start time and its first release time when the start time is in the past.

The RTSJ provides two types of objects which implement the `Schedulable` interface: realtime threads and asynchronous event handlers. This chapter defines the facilities that are available to realtime threads. In many cases these facilities are also available to asynchronous event handlers. In particular:

- the default scheduler must support the scheduling of both realtime threads and asynchronous event handlers;
- realtime threads and asynchronous event handlers are allowed to enter into memory areas and consequently they have associated scope stacks;

- the flow of control of realtime threads and asynchronous event handlers are affected by the RTSJ asynchronous transfer of control facilities;

Where the semantics apply to both realtime threads and asynchronous event handlers, the term *schedulable* will be used.

5.2 Semantics

Instances of `RealtimeThread` have the same semantics as conventional Java threads except as noted below.

1. Garbage collection executing in the context of a Java thread must not in itself block execution of a realtime thread with a higher execution eligibility that may not access the heap; however application locks work as specified even when the lock causes synchronization between a heap-using thread and a realtime thread that may not use the heap.
2. Each realtime thread has an attribute which indicates whether an `AsynchronouslyInterruptedException` is pending. This attribute is set when a call to `RealtimeThread.interrupt()` is made on the associated realtime thread, and when an asynchronously interrupted exception's `fire` method is invoked between the time the realtime thread has entered that exception's `doInterruptible` method, and before it has return from `doInterruptible`. (See Chapter 8 on *Asynchrony*.)
3. A call to `RealtimeThread.interrupt()` generates the system's generic `AsynchronouslyInterruptedException`. (See Chapter 8 on *Asynchrony*.)
4. The `RealtimeThread.waitForNextRelease` method is for use by realtime threads that have periodic or aperiodic release parameters. In the absence of any deadline miss or cost overrun, or an interrupt, the method returns when the realtime thread's next period is due or the next release happens.
5. In the presence of a cost overrun or a deadline miss, the behavior of `waitForNextRelease` is governed by the thread's scheduler.
6. The first release time of a realtime thread is governed by the value of any `start` time in its associated `ReleaseParameter` object and the time at which the `RealtimeThread.start` method is called and the value of any `PhasingPolicy` parameter passed to it.
7. Instances of `RealtimeThread` may not be created with a thread group which is not an instance of `SchedulingGroup`.
8. System-related termination activity (such as execution of finalizers for scoped objects in scoped memory areas that become unreferenced) triggered by termination of a realtime thread is not subject to cost enforcement or deadline miss detection.
9. the scheduling of a realtime thread is governed by its `SchedulingParameters`

and `Scheduler` unless set explicitly with `java.lang.Thread.setPriority(int)`, which causes it to be treated as a conventional java thread until a new `SchedulingParameters` object is set.

5.3 Package *javax.realtime*

5.3.1 Enumerations

5.3.1.1 PhasingPolicy

Inheritance

```
java.lang.Object
  java.lang.Enum
    javax.realtime.PhasingPolicy
```

This class defines a set of constants that specify the supported policies for starting a periodic thread or periodic timer, when it is started later than the assigned absolute time. The following table specifies the effective start time (that is, the first release time of a periodic real-time thread). The effective start time of a periodic timer is similar; where the first firing is equivalent to the first release.

5.3.1.1.1 Enumeration Constants

ADJUST_IMMEDIATE

```
public static final ADJUST_IMMEDIATE
```

ADJUST_FORWARD

```
public static final ADJUST_FORWARD
```

ADJUST_BACKWARD

```
public static final ADJUST_BACKWARD
```

STRICT_PHASING

```
public static final STRICT_PHASING
```

5.3.1.1.2 Methods

Table 5.1: Effect of PhasingPolicy on the First Release of a RealtimeThread with PeriodicParameters

	ADJUST IMMEDIATE	ADJUST FORWARD	ADJUST BACKWARD	STRICT PHASING
Relative Time	The time of start method invocation plus start time.	The time of start method invocation plus start time.	The time of start method invocation plus start time.	The time of start method invocation plus start time.
Absolute Time, earlier than call to start	Release immediately and set next release time to be at the time the start method was invoked plus period .	All releases before the time start is called are ignored. The first release is at the start time plus the smallest multiple of period whose time is after the time start was called.	The first release occurs immediately and the next release is at the start time plus the smallest multiple of period whose time is after the time start was called.	The start method throws an exception.
Absolute Time, later than call to start	First release is at time passed to start .	First release is at time passed to start .	First release is at time passed to start .	First release is at time passed to start .
Without Time	First release is at time of start method invocation	First release is at time of start method invocation	First release is at time of start method invocation	First release is at time of start method invocation

values

Signature

```
public static  
javax.realtime.PhasingPolicy[] values()
```

valueOf(String)

Signature

```
public static  
javax.realtime.PhasingPolicy valueOf(String name)
```

5.3.2 Classes

5.3.2.1 ConfigurationParameters

Inheritance

```
java.lang.Object  
  javax.realtime.ConfigurationParameters
```

Configuration parameters provide a way to specify various implementation-dependent parameters such as the Java stack and native stack sizes, and to configure the statically allocated [ThrowBoundaryError](#)¹ associated with a [Schedulable](#)².

Note that these parameters are immutable.

5.3.2.1.1 Constructors

ConfigurationParameters(int, int, long)

Signature

¹Section [14.3.3.7](#)

²Section [6.4.1.3](#)


```
public
ConfigurationParameters(int messageLength,
                        int stackTraceLength,
                        long[] sizes)
    throws IllegalStateException
```

Creates a parameter object for initializing the state of a [Schedulable](#)³. The parameters provide the data for this initialization. For [RealtimeThread](#)⁴ and bound versions of [AsyncBaseEventHandler](#)⁵, the stack and message buffers can be set exactly, but for the unbound event handlers, the system cannot give any guarantees to allow thread sharing.

Parameters

messageLength Memory space in bytes dedicated to the message associated with [Schedulable](#)⁶ objects created with these parameters' preallocated exceptions, plus references to the method names/identifiers in the stack trace. The value 0 indicates that no message should be stored. The value of -1 uses the system default and is the default when an instance of this class is not provided.

stackTraceLength Length of the stack trace buffer dedicated to [Schedulable](#)⁷ objects created with these parameters' preallocated exceptions, in frames. The amount of space this requires is implementation-specific. The value 0 indicates that no stack trace should be stored. The value of -1 uses the system default and is the default when an instance of this class is not provided.

sizes An array of implementation-specific values dictating memory parameters for [Schedulable](#) objects created with these parameters, such as maximum Java and native stack sizes. The **sizes** array will not be stored in the constructed object. The default is system dependent when set to **null** or an instance of this class is not provided.

Throws

IllegalStateException when **mayUseHeap** is **false** and **area** is an instance of [HeapMemory](#)⁸.

ConfigurationParameters(long)

³Section [6.4.1.3](#)

⁴Section [5.3.2.2](#)

⁵Section [8.4.3.3](#)

⁶Section [6.4.1.3](#)

⁷Section [6.4.1.3](#)

⁸Section [11.4.2.1](#)

Signature

```
public  
ConfigurationParameters(long[] sizes)
```

Same as `ConfigurationParameters(int,int,long[])`⁹ with arguments -1, -1, sizes.

5.3.2.1.2 Methods

getMessageLength*Signature*

```
public  
int getMessageLength()
```

Gets the memory space in bytes dedicated to the message associated with `Schedulable`¹⁰ objects created with these parameters' preallocated exceptions, plus references to the method names/identifiers in the stack trace. The value 0 indicates that no message will be stored.

Returns

Reserved memory size in bytes.

getStackTraceLength*Signature*

```
public  
int getStackTraceLength()
```

Gets the length of the stack trace buffer dedicated to `Schedulable`¹¹ objects created with these parameters' preallocated exceptions, in frames. The amount of space this requires is implementation-specific. The value 0 indicates that no stack trace will be stored.

Returns

Reserved memory size in implementation-dependent stack frames.

⁹Section 5.3.2.1.1

¹⁰Section 6.4.1.3

¹¹Section 6.4.1.3

getSizes

Signature

```
public  
long[] getSizes()
```

Gets the array of implementation-specific sizes associated with [Schedulable](#)¹² objects created with these parameters. *This method may allocate memory.*

Returns

Array of implementation-specific sizes.

5.3.2.2 RealtimeThread

Inheritance

```
java.lang.Object  
  java.lang.Thread  
    javax.realtime.RealtimeThread
```

Interfaces

```
BoundSchedulable  
AsyncTimable
```

Class `RealtimeThread` extends `Thread` and adds access to realtime services such as asynchronous transfer of control, nonheap memory, and advanced scheduler services.

As with `java.lang.Thread`, there are two ways to create a usable `RealtimeThread`.

- Create a new class that extends `RealtimeThread` and override the `run()` method with the logic for the thread.
- Create an instance of `RealtimeThread` using one of the constructors with a `logic` parameter. Pass a `Runnable` object whose `run()` method implements the logic of the thread.

5.3.2.2.1 Constructors

RealtimeThread(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, ConfigurationParameters, TimeDispatcher, SchedulingGroup, Runnable)

¹²Section [6.4.1.3](#)

Signature

```
public
RealtimeThread(SchedulingParameters scheduling,
                ReleaseParameters release,
                MemoryParameters memory,
                MemoryArea area,
                ConfigurationParameters sizing,
                TimeDispatcher dispatcher,
                SchedulingGroup group,
                Runnable logic)
```

Create a realtime thread with the given characteristics and a specified `Runnable`. The scheduling group of the new thread is inherited from its creator unless `group` is set. The newly-created realtime thread is associated with the scheduler in effect during execution of the constructor.

Parameters

scheduling The [SchedulingParameters](#)¹³ associated with `this` (And possibly other instances of [Schedulable](#)¹⁴). When `scheduling` is `null` and the creator is a schedulable, [SchedulingParameters](#)¹⁵ is a clone of the creator's value created in the same memory area as `this`. When `scheduling` is `null` and the creator is a Java thread, the contents and type of the new [SchedulingParameters](#) object is governed by the associated scheduler.

release The [ReleaseParameters](#)¹⁶ associated with `this` (and possibly other instances of [Schedulable](#)¹⁷). When `release` is `null` the new [RealtimeThread](#) will use a clone of the default [ReleaseParameters](#) for the associated scheduler created in the memory area that contains the [RealtimeThread](#) object.

memory The [MemoryParameters](#)¹⁸ associated with `this` (and possibly other instances of [Schedulable](#)¹⁹). When `memory` is `null`, the new [RealtimeThread](#) receives `null` value for its memory parameters, and the amount or rate of memory allocation for the new thread is unrestricted.

area the initial memory area of this handler.

¹³Section [6.4.2.13](#)

¹⁴Section [6.4.1.3](#)

¹⁵Section [6.4.2.13](#)

¹⁶Section [6.4.2.9](#)

¹⁷Section [6.4.1.3](#)

¹⁸Section [11.4.2.4](#)

¹⁹Section [6.4.1.3](#)

sizing The [ConfigurationParameters](#)²⁰ associated with **this** (and possibly other instances of [Schedulable](#)²¹). When **sizing** is **null**, this **RealtimeThread** will reserve no space for preallocated exceptions and implementation-specific values will be set to their implementation-defined defaults.

dispatcher The [TimeDispatcher](#)²² to use for realtime sleep and determining the period of a periodic thread.

group The **SchedulingGroup** of the newly created realtime thread or the parent's scheduling group when **null**.

logic The **Runnable** object whose **run()** method will serve as the logic for the new **RealtimeThread**. When **logic** is **null**, the **run()** method in the new object will serve as its logic.

Throws

IllegalArgumentException when the parameters are not compatible with the associated scheduler or the current thread group is not a **SchedulingGroup** and **group** is **null**.

IllegalAssignmentError when the new **RealtimeThread** instance cannot hold a reference to any of the values of **scheduling**, **release**, **memory** or **group**, when those parameters cannot hold a reference to the new **RealtimeThread**, when the new **RealtimeThread** instance cannot hold a reference to the values of **area** or **logic**, when the initial memory area is not specified and the new **RealtimeThread** instance cannot hold a reference to the default initial memory area, and when the thread may not use the heap, as specified by its configuration, and any of the following is true:

- the initial memory area is not specified,
- the initial memory is heap memory,
- the initial memory area, scheduling, release, memory, or group is allocated in heap memory.
- when this is in heap memory, or
- logic is in heap memory.

RealtimeThread(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, ConfigurationParameters, Runnable)

Signature

²⁰Section [5.3.2.1](#)

²¹Section [6.4.1.3](#)

²²Section [10.4.2.4](#)

```

public
RealtimeThread(SchedulingParameters scheduling,
                ReleaseParameters release,
                MemoryParameters memory,
                MemoryArea area,
                ConfigurationParameters configuration,
                Runnable logic)

```

Create a realtime thread with the given [SchedulingParameters](#)²³, [ReleaseParameters](#)²⁴, [MemoryParameters](#)²⁵, [ConfigurationParameters](#)²⁶, a specified `Runnable`, and default values for all other parameters.

This constructor is equivalent to `RealtimeThread(scheduling, release, memory, area, configuration, null, null, logic)`.

RealtimeThread(SchedulingParameters, ReleaseParameters, ConfigurationParameters, Runnable)

Signature

```

public
RealtimeThread(SchedulingParameters scheduling,
                ReleaseParameters release,
                ConfigurationParameters configuration,
                Runnable logic)

```

Create a realtime thread with the given [SchedulingParameters](#)²⁷, [ReleaseParameters](#)²⁸, [MemoryArea](#)²⁹ and a specified `Runnable` and default values for all other parameters.

This constructor is equivalent to `RealtimeThread(scheduling, release, configuration, null, null, null, logic)`.

RealtimeThread(SchedulingParameters, ReleaseParameters, ConfigurationParameters)

²³Section [6.4.2.13](#)

²⁴Section [6.4.2.9](#)

²⁵Section [11.4.2.4](#)

²⁶Section [5.3.2.1](#)

²⁷Section [6.4.2.13](#)

²⁸Section [6.4.2.9](#)

²⁹Section [11.4.2.3](#)

Signature

```
public
RealtimeThread(SchedulingParameters scheduling,
                ReleaseParameters release,
                ConfigurationParameters configuration)
```

Create a realtime thread with the given [SchedulingParameters](#)³⁰, [ReleaseParameters](#)³¹ and [MemoryArea](#)³² and default values for all other parameters.

This constructor is equivalent to `RealtimeThread(scheduling, release, null, null, configuration, null, null, null)`.

RealtimeThread(SchedulingParameters, ReleaseParameters, Runnable)

Signature

```
public
RealtimeThread(SchedulingParameters scheduling,
                ReleaseParameters release,
                Runnable logic)
```

Create a realtime thread with the given [SchedulingParameters](#)³³, [ReleaseParameters](#)³⁴ and a specified `Runnable` and default values for all other parameters.

This constructor is equivalent to `RealtimeThread(scheduling, release, null, null, null, null, null, logic)`.

RealtimeThread(SchedulingParameters, ReleaseParameters)

Signature

```
public
RealtimeThread(SchedulingParameters scheduling,
```

³⁰Section [6.4.2.13](#)

³¹Section [6.4.2.9](#)

³²Section [11.4.2.3](#)

³³Section [6.4.2.13](#)

³⁴Section [6.4.2.9](#)

```
ReleaseParameters release)
```

Create a realtime thread with the given [SchedulingParameters](#)³⁵ and [ReleaseParameters](#)³⁶ and default values for all other parameters.

This constructor is equivalent to `RealtimeThread(scheduling, release, null, null, null, null, null, null)`.

RealtimeThread(SchedulingParameters, TimeDispatcher)

Signature

```
public  
RealtimeThread(SchedulingParameters scheduling,  
               TimeDispatcher dispatcher)
```

Create a realtime thread with the given [SchedulingParameters](#)³⁷ and [TimeDispatcher](#)³⁸ and default values for all other parameters. This constructor is equivalent to `RealtimeThread(scheduling, null, null, null, null, dispatcher, null, null)`.

RealtimeThread(SchedulingParameters)

Signature

```
public  
RealtimeThread(SchedulingParameters scheduling)
```

Create a realtime thread with the given [SchedulingParameters](#)³⁹ and default values for all other parameters. This constructor is equivalent to `RealtimeThread(scheduling, null, null, null, null, null, null, null)`.

RealtimeThread

Signature

³⁵Section [6.4.2.13](#)

³⁶Section [6.4.2.9](#)

³⁷Section [6.4.2.13](#)

³⁸Section [10.4.2.4](#)

³⁹Section [6.4.2.13](#)


```
public  
RealtimeThread()
```

Create a realtime thread with default values for all parameters. This constructor is equivalent to `RealtimeThread(null, null, null, null, null, null, null)`.

5.3.2.2.2 Methods

currentRealtimeThread

Signature

```
public static  
javafx.realtime.RealtimeThread currentRealtimeThread()  
throws ClassCastException
```

Gets a reference to the current instance of `RealtimeThread`.

It is permissible to call `currentRealtimeThread` when control is in an [Async-EventHandler](#)⁴⁰. The method will return a reference to the `RealtimeThread` supporting that release of the async event handler.

Throws

`ClassCastException` when the current execution context is that of a Java thread.

Returns

A reference to the current instance of `RealtimeThread`.

getCurrentMemoryArea

Signature

```
public static  
javafx.realtime.MemoryArea getCurrentMemoryArea()
```

Return a reference to the [MemoryArea](#)⁴¹ object representing the current allocation context.

When this method is invoked from a Java thread it will return that thread's current memory area (heap or immortal memory).

Returns

⁴⁰Section [8.4.3.5](#)

⁴¹Section [11.4.2.3](#)

A reference to the [MemoryArea](#)⁴² object representing the current allocation context.

getInitialMemoryAreaIndex

Signature

```
public static  
int getInitialMemoryAreaIndex()  
throws IllegalStateException,  
    ClassCastException
```

Gets the position of the initial memory area for the current [Schedulable](#)⁴³ in the memory area stack. Memory area stacks may include inherited stacks from parent threads. The initial memory area of a [RealtimeThread](#)⁴⁴ or an [AsyncBaseEventHandler](#)⁴⁵ is the memory area specified in its constructor. The index of the initial memory area in the initial memory area stack is a fixed property of a [Schedulable](#).

When the current memory area stack of the current realtime thread is not the original stack and the memory area at the initial memory area index is not the initial memory area, then `IllegalStateException` is thrown.

Throws

`IllegalThreadStateException` when the memory area stack of the current `RealtimeThread` has changed from its initial configuration and the memory area at the originally specified initial memory area index is not the initial memory area.

`ClassCastException` when the current execution context is that of a Java thread.

Returns

The index into the initial memory area stack of the initial memory area of the current `RealtimeThread`.

getMemoryAreaStackDepth

Signature

```
public static  
int getMemoryAreaStackDepth()
```

⁴²Section [11.4.2.3](#)

⁴³Section [6.4.1.3](#)

⁴⁴Section [5.3.2.2](#)

⁴⁵Section [8.4.3.3](#)

throws `ClassCastException`

Gets the size of the stack of `MemoryArea`⁴⁶ instances to which the current schedulable has access.

Note: The current memory area (`getCurrentMemoryArea()`⁴⁷) is found at memory area stack index of `getMemoryAreaStackDepth() - 1`.

Throws

`ClassCastException` when the current execution context is that of a Java thread.

Returns

The size of the stack of `MemoryArea`⁴⁸ instances.

`getOuterMemoryArea(int)`

Signature

```
public static
  javax.realtime.MemoryArea getOuterMemoryArea(int index)
  throws ClassCastException,
         MemoryAccessError
```

Gets the instance of `MemoryArea`⁴⁹ in the memory area stack at the index given. When the given index does not exist in the memory area scope stack then `null` is returned.

Note: The current memory area (`getCurrentMemoryArea()`⁵⁰) is found at memory area stack index `getMemoryAreaStackDepth() - 1`, so `getCurrentMemoryArea() == getOuterMemoryArea(getMemoryAreaStackDepth() - 1)`.

Parameters

`index` The offset into the memory area stack.

Throws

`ClassCastException` when the current execution context is that of a Java thread.

`MemoryAccessError` when the memory area is allocated in heap memory and the caller is a schedulable that may not use the heap.

Returns

⁴⁶Section 11.4.2.3

⁴⁷Section 5.3.2.2.2

⁴⁸Section 11.4.2.3

⁴⁹Section 11.4.2.3

⁵⁰Section 5.3.2.2.2

The instance of [MemoryArea](#)⁵¹ at index or `null` when the given value does not correspond to a position in the stack.

sleep(HighResolutionTime)

Signature

```
public static
void sleep(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException,
      ClassCastException,
      IllegalArgumentException
```

A sleep method that is controlled by a generalized clock. Since the time is expressed as a [HighResolutionTime](#)⁵², this method is an accurate timer with nanosecond granularity. The actual resolution available for the clock and even the quantity it measures depends on `clock`. The time base is the given [Clock](#)⁵³. The sleep time may be relative or absolute. When relative, then the calling thread is blocked for the amount of time given by `time`, and measured by `clock`. When absolute, then the calling thread is blocked until the indicated value is reached by `clock`. When the given absolute time is less than or equal to the current value of `clock`, the call to sleep returns immediately.

It is permissible to call `sleep` when control is in an [AsyncEventHandler](#)⁵⁴. The method cause the handler to sleep.

This method must not throw `IllegalAssignmentError`. It must tolerate `time` instances that may not be stored in `this`.

Parameters

`time` The amount of time to sleep or the point in time at which to awaken.

Throws

`InterruptedException` when the thread is interrupted by [interrupt\(\)](#)⁵⁵ or [AsynchronouslyInterruptedException.fire\(\)](#)⁵⁶ during the time between calling this method and returning from it.

`ClassCastException` when the current execution context is that of a Java thread.

⁵¹Section [11.4.2.3](#)

⁵²Section [9.4.1.2](#)

⁵³Section [10.4.2.1](#)

⁵⁴Section [8.4.3.5](#)

⁵⁵Section [5.3.2.2.2](#)

⁵⁶Section [8.4.2.1.2](#)

`IllegalArgumentException` when `time` is null, when `time` is a relative time less than zero, or when the `Chronograph`⁵⁷ of `time` is not a `Clock`⁵⁸.

suspend(HighResolutionTime)

Signature

```
public static
void suspend(javax.realtime.HighResolutionTime<?> time)
throws ClassCastException,
       IllegalArgumentException
```

The same as `sleep(HighResolutionTime)`⁵⁹ except that it is not interruptible.

Parameters

`time` an absolute or relative time until which to suspend.

Throws

`ClassCastException` when the current execution context is that of a Java thread.

`IllegalArgumentException` when `time` is null, when `time` is a relative time less than zero, or when the `Chronograph`⁶⁰ of `time` is not a `Clock`⁶¹.

spin(HighResolutionTime)

Signature

```
public static
void spin(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException,
       ClassCastException,
       IllegalArgumentException
```

Similar to `sleep(HighResolutionTime)`⁶² except it performs a busy wait by polling on the `Chronograph`⁶³ in `time`.

Parameters

`time` an absolute or relative time at which to stop spinning.

⁵⁷Section 10.4.1.2

⁵⁸Section 10.4.2.1

⁵⁹Section 5.3.2.2.2

⁶⁰Section 10.4.1.2

⁶¹Section 10.4.2.1

⁶²Section 5.3.2.2.2

⁶³Section 10.4.1.2

Throws

`InterruptedException` when the thread is interrupted by `interrupt()`⁶⁴ or `AsynchronouslyInterruptedException.fire()`⁶⁵ during the time between calling this method and returning from it.

`ClassCastException` when the current execution context is that of a Java thread.

`IllegalArgumentException` when `time` is `null`, or when `time` is a relative time less than zero.

spin(int)*Signature*

```
public static
void spin(int nanos)
throws InterruptedException,
        ClassCastException,
        IllegalArgumentException
```

The same as calling `spin(HighResolutionTime)`⁶⁶ with a relative time to the default realtime clock, zero milliseconds, and `nanos` nanoseconds, except no relative time object is necessary.

Parameters

`nanos` a relative number of nanoseconds to wait.

Throws

`InterruptedException` when the thread is interrupted by `interrupt()`⁶⁷ or `AsynchronouslyInterruptedException.fire()`⁶⁸ during the time between calling this method and returning from it.

`ClassCastException` when the current execution context is that of a Java thread.

`IllegalArgumentException` when `nanos` is less than zero.

waitForNextRelease*Signature*

⁶⁴Section 5.3.2.2.2

⁶⁵Section 8.4.2.1.2

⁶⁶Section 5.3.2.2.2

⁶⁷Section 5.3.2.2.2

⁶⁸Section 8.4.2.1.2

```

public static
boolean waitNextRelease()
throws AsynchronouslyInterruptedException,
        IllegalStateException,
        ClassCastException

```

Causes the current realtime thread to delay until the next release. (See `release()`⁶⁹.) Used by threads that have a reference to either periodic or aperiodic `ReleaseParameters`⁷⁰. The first release starts when `this` thread is released as a consequence of the action of one of the `start()`⁷¹ family of methods. Each time this method is called it will block until the next release unless the thread is in a deadline miss condition. In that case, the operation of `waitNextRelease` is controlled by this thread's scheduler. (See `PriorityScheduler`⁷².)

Throws

`AsynchronouslyInterruptedException` when the thread is interrupted by `interrupt()`⁷³ or `AsynchronouslyInterruptedException.fire()`⁷⁴ during the time between calling this method and returning from it and the `ReleaseParameters.isRousable()`⁷⁵ on its release parameters returns `true`.

An interrupt during `waitNextPeriodInterruptible` is treated as a release for purposes of scheduling. This is likely to disrupt proper operation of the periodic thread. The timing behavior of the thread is unspecified until the state is reset by altering the thread's release parameters or the thread is no longer in a deadline miss state.

`IllegalStateException` when `this` does not have a reference to a `ReleaseParameters`⁷⁶ type of either `PeriodicParameters`⁷⁷ or `AperiodicParameters`⁷⁸.

`ClassCastException` when the current thread is not an instance of `RealtimeThread`.

Returns

Either `false` when the thread is in a deadline miss condition or `true` otherwise. When a deadline miss condition occurs is defined by its thread's scheduler.

⁶⁹Section 5.3.2.2.2

⁷⁰Section 6.4.2.9

⁷¹Section 5.3.2.2.2

⁷²Section 6.4.2.7

⁷³Section 5.3.2.2.2

⁷⁴Section 8.4.2.1.2

⁷⁵Section 6.4.2.9.2

⁷⁶Section 6.4.2.9

⁷⁷Section 6.4.2.5

⁷⁸Section 6.4.2.2

release

Signature

```
public  
void release()
```

Generate a release for this `RealtimeThread`. The action of this release is governed by the scheduler. It may, for instance, act immediately, or be queued, delayed, or discarded.

Throws

`IllegalStateException` when `this` does not have a reference to a `ReleaseParameters`⁷⁹ type of `AperiodicParameters`⁸⁰.

deschedule

Signature

```
public  
void deschedule()
```

When the `ReleaseParameters`⁸¹ object associated with `this` `RealtimeThread` is an instance of is `AperiodicParameters`⁸², perform any *deschedule* actions specified by this thread's scheduler. When the type of the associated instance of `ReleaseParameters`⁸³ is not `AperiodicParameters`⁸⁴ nothing happens.

getMemoryArea

Signature

```
public  
javax.realtime.MemoryArea getMemoryArea()
```

Return the initial memory area for this `RealtimeThread`. When not specified through the constructor, the default is a *reference* to the current allocation context when `this` was constructed.

Returns

⁷⁹Section 6.4.2.9

⁸⁰Section 6.4.2.2

⁸¹Section 6.4.2.9

⁸²Section 6.4.2.2

⁸³Section 6.4.2.9

⁸⁴Section 6.4.2.2

A reference to the initial memory area for this thread.

getMemoryParameters

Signature

```
public  
javax.realtime.MemoryParameters getMemoryParameters()
```

Returns

getSchedulingGroup

Signature

```
public  
javax.realtime.SchedulingGroup getSchedulingGroup()
```

Returns

getConfigurationParameters

Signature

```
public  
javax.realtime.ConfigurationParameters getConfigurationParameters()
```

Returns

getReleaseParameters

Signature

```
public  
javax.realtime.ReleaseParameters getReleaseParameters()
```

Returns

getScheduler

Signature

```
public  
    javax.realtime.Scheduler getScheduler()
```

Returns

getSchedulingParameters

Signature

```
public  
    javax.realtime.SchedulingParameters getSchedulingParameters()
```

Returns

interrupt

Signature

```
public  
    void interrupt()
```

Extends the function of `Thread.interrupt()`, generates the generic [AsynchronouslyInterruptedException](#)⁸⁵ and targets it at this, and sets the interrupted state to pending. The semantics of `Thread.interrupt()` are also preserved.

reschedule

Signature

⁸⁵Section [8.4.2.1](#)

```
public
void reschedule()
throws IllegalStateException
```

Begin unblocking `RealtimeThread.waitForNextRelease`⁸⁶ for an periodic thread. When deadline miss detection is disabled, enable it. Typically used when an aperiodic schedulable is in a deadline miss condition.

The details of the interaction of this method with `deschedule`⁸⁷, `waitForNextRelease`⁸⁸ and `release`⁸⁹ are dictated by this thread's scheduler. When this `RealtimeThread` does not have a type of `AperiodicParameters`⁹⁰ as its `ReleaseParameters`⁹¹ nothing happens.

Throws

`IllegalStateException` when the configured Scheduler and Scheduling-Parameters for this `RealtimeThread` are not compatible.

setMemoryParameters(MemoryParameters)

Signature

```
public
void setMemoryParameters(MemoryParameters memory)
```

Parameters

`memory`

Throws

`IllegalArgumentException`
`IllegalAssignmentError`
`IllegalStateException`

setReleaseParameters(ReleaseParameters)

Signature

```
public
void setReleaseParameters(ReleaseParameters release)
```

⁸⁶Section 5.3.2.2.2

⁸⁷Section 5.3.2.2.2

⁸⁸Section 5.3.2.2.2

⁸⁹Section 5.3.2.2.2

⁹⁰Section 6.4.2.2

⁹¹Section 6.4.2.9

Parameters`release`*Throws*`IllegalArgumentException``IllegalAssignmentError``IllegalThreadStateException`**setScheduler(Scheduler)***Signature*

```
public
void setScheduler(Scheduler scheduler)
```

For an instance of `RealtimeThread`, the `Schedulable` is *running* when `RealtimeThread.start()`⁹² has been called on it and `RealtimeThread.join()` would block.

Parameters`scheduler`*Throws*`IllegalArgumentException``IllegalAssignmentError``SecurityException``IllegalThreadStateException`**setScheduler(Scheduler, SchedulingParameters, ReleaseParameters, MemoryParameters)***Signature*

```
public
void setScheduler(Scheduler scheduler,
                  SchedulingParameters scheduling,
                  ReleaseParameters release,
                  MemoryParameters memoryParameters)
```

⁹²Section 5.3.2.2.2

Parameters

scheduler
scheduling
release
memoryParameters

Throws

IllegalArgumentException
IllegalAssignmentError
IllegalThreadStateException
SecurityException

setSchedulingParameters(SchedulingParameters)*Signature*

```
public  
void setSchedulingParameters(SchedulingParameters scheduling)
```

Parameters

scheduling

Throws

IllegalArgumentException
IllegalAssignmentError
IllegalThreadStateException

startPeriodic(PhasingPolicy)*Signature*

```
public  
void startPeriodic(PhasingPolicy phasingPolicy)  
throws LateStartException
```

Start the thread with the specified phasing policy.

Parameters

phasingPolicy The phasing policy to be applied when the start time given in the realtime thread's associated [PeriodicParameters](#)⁹³ is in the past.

⁹³Section [6.4.2.5](#)

Throws

`javax.realtime.LateStartException` when the actual start time is after the assigned start time and the phasing policy is `PhasingPolicy.STRICT_PHASING`⁹⁴.

`IllegalArgumentException` when the thread is not periodic, or when its start time is not absolute.

`IllegalThreadStateException` when the configured `Scheduler` and `SchedulingParameters` for this `RealtimeThread` are not compatible.

start*Signature*

```
public
void start()
```

Set up the realtime thread's environment and start it. The set up might include delaying it until the assigned start time and initializing the thread's scope stack. (See `ScopedMemory`⁹⁵.)

Throws

`IllegalStateException` when the configured `Scheduler` and `SchedulingParameters` for this `RealtimeThread` are not compatible.

getLastReleaseTime*Signature*

```
public
javax.realtime.AbsoluteTime getLastReleaseTime()
```

Equivalent to `getLastReleaseTime(null)`

getLastReleaseTime(AbsoluteTime)*Signature*

```
public
javax.realtime.AbsoluteTime getLastReleaseTime(AbsoluteTime dest)
```

Return the absolute time of this thread's last release, whether periodic or aperiodic.

⁹⁴Section 5.3.1.1.1

⁹⁵Section 15.3.3.11

The clock in the returned absolute time shall be the realtime clock for aperiodic releases and the clock used for the periodic release for periodic releases.

Returns

the last release time in **dest**. When **dest** is **null**, create a new absolute time instance in the current memory area.

getEffectiveStartTime

Signature

```
public  
javax.realtime.AbsoluteTime getEffectiveStartTime()
```

Equivalent to `getEffectiveStartTime(null)`.

getEffectiveStartTime(AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime getEffectiveStartTime(AbsoluteTime dest)
```

Return the effective start time of this realtime thread. This is not necessarily the same as the start time in the release parameters.

- When the release parameters' start time is relative, the effective start time is the time of the first release.
- When the release parameters' start time is an absolute time after `start()` is invoked, the effective start time is the same as the release parameters' start time.
- When the release parameters' start time is an absolute time before `start()` is invoked, the effective start time depends on the phasing policy.

The default is to set the effective start time equal to the time `start()` is invoked.

Returns

The effective start time in **dest**. When **dest** is **null**, return the effective start time in an [AbsoluteTime](#)⁹⁶ instance created in the current memory area.

getCurrentConsumption(RelativeTime)

Signature

⁹⁶Section [9.4.1.1](#)

```
public static  
    javafx.runtime.RelativeTime getCurrentConsumption(RelativeTime dest)
```

Throws

`IllegalStateException` when the caller is not a `RealtimeThread`⁹⁷.

Returns

The CPU consumption for this release. When `dest` is `null`, return the CPU consumption in a `RelativeTime`⁹⁸ instance created in the current execution context. When `dest` is not `null`, return the CPU consumption in `dest`

getCurrentConsumption

Signature

```
public static  
    javafx.runtime.RelativeTime getCurrentConsumption()
```

Equivalent to `getCurrentConsumption(null)`.

getMinConsumption(RelativeTime)

Signature

```
public  
    javafx.runtime.RelativeTime getMinConsumption(RelativeTime dest)
```

Get the minimum CPU consumption measured for any completed release of this thread.

Returns

the minimum CPU consumption in `dest`. When `dest` is `null` return the minimum CPU consumption in a `RelativeTime`⁹⁹ instance created in the current memory area.

getMinConsumption

Signature

```
public  
    javafx.runtime.RelativeTime getMinConsumption()
```

⁹⁷Section 5.3.2.2

⁹⁸Section 9.4.1.3

⁹⁹Section 9.4.1.3

Equivalent to `getMinConsumption(null)`.

getMaxConsumption(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getMaxConsumption(RelativeTime dest)
```

Get the maximum CPU consumption measured for any completed release of this thread.

Returns

the maximum CPU consumption in `dest`. When `dest` is `null` return the maximum CPU consumption in a [RelativeTime¹⁰⁰](#) instance created in the current memory area.

getMaxConsumption

Signature

```
public  
javax.realtime.RelativeTime getMaxConsumption()
```

Equivalent to `getMaxConsumption(null)`.

getDispatcher

Signature

```
public  
javax.realtime.TimeDispatcher getDispatcher()
```

Get the dispatcher responsible for handling sleep requests issued by this thread
See Section [AsyncTimable.getDispatcher\(\)](#)

fire

Signature

¹⁰⁰Section [9.4.1.3](#)

```
public final
void fire()
```

Used by the [Clock](#)¹⁰¹ infrastructure to cause a call to [waitForNextRelease](#)¹⁰² to return.

See [Section AsyncTimable.fire\(\)](#)

mayUseHeap

Signature

```
public
boolean mayUseHeap()
```

Determine whether or not this `schedulable` may use the heap.

Returns

`true` only when this `Schedulable` may allocate on the heap and may enter `HeapMemory`.

awaken

Signature

```
public final
void awaken()
```

Used by the [Clock](#)¹⁰³ infrastructure to cause a call to [sleep](#)¹⁰⁴ to return.

See [Section Schedulable.awaken\(\)](#)

5.4 Rationale

The RTSJ platform's priority-preemptive dispatching model is very similar to the dispatching model found in the majority of commercial realtime operating systems. However, the dispatching semantics were purposefully relaxed in order to allow execution on a wide variety of operating systems. Thus, it is appropriate to specify realtime threads by extending `java.lang.Thread`.

¹⁰¹Section [10.4.2.1](#)

¹⁰²Section [5.3.2.2.2](#)

¹⁰³Section [10.4.2.1](#)

¹⁰⁴Section [5.3.2.2.2](#)

The `ReleaseParameters` and `MemoryParameters` provided to the `RealtimeThread` constructor allow for a number of common realtime thread types, including periodic threads.

The `ConfigurationParameters` class is provided with a no-heap option in order to allow time-critical schedulables to execute in preference to the garbage collector given appropriate assignment of execution eligibility. The memory access and assignment semantics of these no-heap schedulables are designed to guarantee that the execution of such threads does not lead to an inconsistent heap state.

Chapter 6

Scheduling

6.1 Overview

Scheduling is a key differentiator between a conventional Java implementation and a realtime Java implementation. Whereas conventional Java implementations relies on some sort of fair scheduling, a realtime Java implementation must provide a realtime scheduler. In a realtime scheduler, ensuring that critical tasks finish on time is more critical than overall throughput or fairness.

The scheduler required by this specification is fixed-priority preemptive with at least 28 unique priority levels. It is represented by the class `FirstInFirstOutScheduler`, a subclass of `PriorityScheduler`, and is called the *base scheduler*. As the name implies, this scheduler does not time-slice threads at a given priority, but rather runs each to completion, so long as no higher priority thread become ready to run and no other processor is available for the higher priority thread. In that case, the current thread is preempted by the higher priority thread.

The schedulables required by this specification are denoted by the `Schedulable` interface and include the classes `RealtimeThread`, `AsyncEventHandler`, `AsyncLongEventHandler`, `AsyncObjectEventHandler`, and their bounded subclasses. The base scheduler assigns processor resources according to the schedulables' release characteristics, execution eligibility, affinity, and processing group values. Subclasses of these schedulables are also schedulables and behave as these required classes.

The scheduler dispatches a schedulable, that is ready to run, on a CPU. Some systems, such as multicore systems, have more than one CPU to choose from. By default, a ready schedulable would be dispatched on the next available CPU; however, the specification provides an interface, `Affinity` to control, on which sets of CPUs a given schedulable may run.

An instance of the `SchedulingParameters` class contains values of execution eligibility. A schedulable is considered to have the execution eligibility represented

by the **SchedulingParameters** object currently bound to it. For implementations providing only the base scheduler, the scheduling parameters object is an instance of **PriorityParameters** (a subclass of **SchedulingParameters**).

An instance of the **ReleaseParameters** class or its subclasses, **PeriodicParameters**, **AperiodicParameters**, and **SporadicParameters**, contains values that define a particular release characteristic. A schedulable is considered to have the release characteristics of a single associated instance of the **ReleaseParameters** class.

For a realtime thread, the scheduler defines the behavior of the realtime thread's **waitForNextRelease** and **waitForNextReleaseInterruptible** methods. For all **Schedulables**, the scheduler monitors cost overrun and deadline miss conditions based on its release parameters. Release parameters also govern the treatment of the minimum interarrival time for sporadic schedulables.

The **ThreadGroup** class has special significance in an RTSJ implementation. As in conventional Java, the maximum priority of a thread is governed in part by its thread group, but the CPU affinity of a thread is also governed by its thread group along with the **Affinity** class. Furthermore, there are two important subclasses: **SchedulingGroup** and **ProcessingGroup**. These classes provide additional means of managing tasks.

An instance of the **SchedulingGroup** provides scheduling constraints for schedulables similar to how a **ThreadGroup** does for convention Java threads. The scheduler and maximum **SchedulingParameters** can be set. In fact, a schedulable can only be created in an instance of **SchedulingParameters** or its subclass. Therefore the root thread group and the thread group of the initial thread must both be scheduling groups in an RTSJ implementation.

The **ProcessingGroup** class is a subclass of **SchedulingGroup**. An instance of the **ProcessingGroup** class contains values that define a temporal scope for a processing group. When a schedulable has an associated instance of the **ProcessingGroup** class, it is said to execute within the temporal scope defined by that instance. A single instance of the **ProcessingGroup** class can be, and typically is, associated with many schedulables. In an implementation that supports cost enforcement, the combined processor demand of all of the schedulables associated with an instance of the **ProcessingGroup** class must not exceed the values in that instance (i.e., the defined temporal scope). The processor demand is determined by the **Scheduler**.

The scheduling classes provide the necessary support for realtime scheduling. These classes

- enable the definition of schedulables,
- manage the assignment of execution eligibility to schedulable objects,
- manage the execution of instances of the **AsyncBaseEventHandler** and **Real-timeThread** classes,
- assign release characteristics to schedulables,

- assign execution eligibility values to schedulables, and
- manage the execution of groups of schedulables that collectively exhibit additional release characteristics.

6.2 Definitions

Task is the name given to a unit of independent execution. In conventional Java, this is a thread. The **Schedulable** interface marks realtime tasks. The classes that implement **Schedulable** are subject to the scheduling behavior of realtime schedulers. Instances of these classes are referred to as *Schedulables* (SO) and provide three execution states: *executing*, *blocked*, and *eligible-for-execution*.

- *Executing* refers to the state where the schedulable is currently running on a processor.
- *Blocked* refers to the state where the schedulable is not among those schedulables that could be selected to have their state changed to executing. The blocked state will have a reason associated with it, e.g., blocked-for-I/O-completion, blocked-for-release-event, or blocked-by-cost-overflow.
- *Eligible-for-execution* refers to the state where the schedulable could be selected to have its state changed to executing.

Each type of schedulable defines its own *release events*, for example, the release events for a periodic schedulable are caused by the passage of time and occur at programmatically specified intervals.

Release is the changing of the state of a schedulable from blocked-for-release-event to eligible-for-execution. When the state of a schedulable is blocked-for-release-event and a release event occurs then the state of the schedulable is changed to eligible-for-execution. Otherwise, a state transition from blocked-for-release-event to eligible-for-execution is queued; this is known as a *pending release*. When the next transition of the schedulable into state blocked-for-release-event occurs, and there is a pending release, the state of the schedulable is immediately changed to eligible-for-execution. (Some actions implicitly clear any pending releases.)

Completion is the changing of the state of a schedulable from executing to blocked-for-release-event. Each completion corresponds to a release. A realtime thread is deemed to complete its most recent release when it terminates.

Deadline refers to a time before which a schedulable expects to complete. The i^{th} deadline is associated with the i^{th} release event and a *deadline miss* occurs when the i^{th} completion would occur after the i^{th} deadline.

Deadline monitoring is the process by which the implementation responds to deadline misses. When a deadline miss occurs for a schedulable object, the deadline miss handler, if any, for that schedulable is released. This behaves as if there were an asynchronous event associated with the schedulable, to which the miss handler

was bound, and which was fired when the deadline miss occurred.

Periodic, *sporadic*, and *aperiodic* are adjectives applied to schedulables which describe the temporal relationship between consecutive release events. Let R_i denote the time at which a schedulable has had the i^{th} release event occur. Ignoring the effect of release jitter:

- a schedulable is periodic when there exists a value $T > 0$ such that for all i , $R_{i+1} - R_i = T$, where T is called the period;
- a schedulable that is not periodic is said to be aperiodic; and
- an aperiodic schedulable is said to be sporadic when there is a known value $T > 0$ such that for all i , $R_{i+1} - R_i \geq T$. T is then called the minimum interarrival time (MIT).

The *cost* of a schedulable is an estimate of the maximum amount of CPU time that the schedulable requires between a release and its associated completion.

The *current CPU consumption* of a schedulable is the amount of CPU time that the schedulable has consumed since its last release.

A *cost overrun* occurs when the schedulable's current CPU consumption becomes greater than, or equal to, its cost.

Cost monitoring is the process by which the implementation tracks CPU consumption and responds to cost overruns. When a cost overrun occurs for a schedulable, the cost overrun handler, if any, for that schedulable is released. This behaves as if there were an asynchronous event associated with the schedulable, to which the overrun handler was bound, and which was fired when the cost overrun occurred.

Cost enforcement is the process by which the implementation ensures that the CPU consumption of a schedulable is no more than the value of the cost parameter in its associated `ReleaseParameters`. (Cost enforcement is an optional facility in an implementation of the RTSJ.)

The *base priority* of a schedulable is the priority given in its associated `PriorityParameters` object; the base priority of a Java thread is the priority returned by its `getPriority` method.

When it is not in the enforced state, the *active priority* of a schedulable or a Java thread is the maximum of its base priority and any priority it has acquired due to the action of priority inversion avoidance algorithms (see the *Synchronization Chapter*).

A *processing group* is a collection of schedulables whose combined execution has further execution time constraints which the scheduler uses to govern the group's execution eligibility.

A *scheduler* manages the execution of schedulables: it detects deadline misses and monitors costs. It also manages the execution of Java threads.

The *base scheduler* is an instance of the `FirstInFirstOutScheduler` class as defined in this specification. This is the initial default scheduler.

The *round-robin scheduler* is an instance of the `RoundRobinScheduler` class as defined in this specification. It is specified to execute in tandem with the base scheduler in a predictable fashion.

A *processor* is a logical processing element that is capable of physically executing a single thread of control at any point in time. Hence, multicore platforms have multiple processors, platforms that support hyperthreading also have more than one processor. It is assumed that all processors are capable of executing the same instruction sets.

An *affinity* is a set of processors on which the global scheduling of a schedulable can be supported.

6.3 Semantics

Scheduling semantics determined which task run when. Both *The Java Virtual Machine Specification*[6] and *The Java Language Specification*[5] are silent on the semantics for scheduling; only for semantics for synchronization is provided. Since scheduling is central to realtime programming, here is a detail semantic applicable across the classes defined below, along with definitions of the required scheduling algorithms. Semantics that apply to particular classes, constructors, methods, and fields can be found in the class description and the constructor, method, and field detail sections.

6.3.1 Schedulers

There are four basic requirements for schedulers.

1. A scheduler may only change the execution eligibility of the schedulables which it manages and only in accordance with its scheduling algorithm.
2. Each scheduler provided for application code by an RTSJ implementation must have documentation describing its semantics including at least the following: the algorithm used to determine eligibility, what schedulables may be scheduled by it, the subclasses of `Scheduler` and `SchedulingParameters` used to control the scheduler, and any other classes needed by the scheduler.
3. Every implementation must provide a round robin scheduler and a first in first out scheduler using priorities above the ten (1–10) conventional Java priorities as documented below.
4. Tasks with a convention Java priority (1–10) should be scheduled such that when two or more threads run at the same priority, one thread cannot block another indefinitely and not violate the requirements dictated by `java.lang.Thread`.

The scheduler can be changed independently of the `SchedulingParameters` and visa versa only when the `Schedulable` in question is descheduled. Rescheduling will

throw an `illegalStateException` when called on a `Schedulable` that has inconsistent scheduler and Scheduling parameters. Trying to add a handler with `SchedulingParameters` that do not match its scheduler to an event will also result in an `illegalStateException` being thrown.

6.3.2 The Base Scheduler

The semantics for the base scheduler assume a uniprocessor or shared memory multiprocessor execution environment. Scheduling is priority preemptive with run to completion, also known as first-in-first-out (FIFO) semantics. The base scheduler supports the execution of all schedulables.

6.3.2.1 Priorities

The base scheduler is a priority scheduler with the following requirements.

1. The base scheduler must support at least 28 distinct values (realtime priorities) that can be stored in an instance of `PriorityParameters` in addition to the values 1 through 10 required to support the priorities defined by `java.lang.Thread`.
2. The realtime priority values must be greater than 10, and they must include all integers from the base scheduler's `getMinPriority()` value to its `getMaxPriority()` value inclusive.
3. Higher priority values in an instance of `PriorityParameters` have a higher execution eligibility.
4. The 10 priorities defined for `java.lang.Thread` must effectively have lower execution eligibility than the realtime priorities.
5. When the round-robin scheduler is present, the base scheduler must support at least one priority value numerically greater than the maximum allowable round-robin priority.
6. For realtime scheduling, the base priority of each `Schedulable` under the control of the base scheduler must be from the range of realtime priorities. A `Schedulable` with a priority in the `java.lang.Thread` range will be scheduled as if it were an instance of `java.lang.Thread`.
7. Assignment of any of the realtime priority values to any `Schedulable` controlled by the base priority scheduler is legal. It is the responsibility of application logic to make rational priority assignments.
8. The base scheduler does not use the `importance` value in the `ImportanceParameters` subclass of `PriorityParameters`.
9. Calling the `java.lang.Thread.setPriority` on a thread can only be used to set the thread's priority to a conventional Java priority (1–10).

10. For schedulables managed by the base scheduler, the implementation must not change the execution eligibility for any reason other than
 - (a) the implementation of a priority inversion avoidance algorithm requires it, or
 - (b) as a result of a program's request to change the priority parameters associated with one or more schedulables; e.g., by changing a value in a scheduling parameter object that is used by one or more schedulables, or by using `setSchedulingParameters()` to give a schedulable a different `SchedulingParameters` value.
11. Use of `Thread.setPriority()`, any of the methods defined for schedulables, or any of the methods defined for parameter objects must not affect the correctness of the priority inversion avoidance algorithms controlled by `PriorityCeilingEmulation` and `PriorityInheritance`—see the *Synchronization* chapter.
12. When schedulable *A* managed by the base scheduler creates a Java thread, *B*, then the initial base priority of *B* is the minimum of the priority value returned by the `getMaxPriority` method of *B*'s `java.lang.ThreadGroup` object and the priority of *A*.
13. `PriorityScheduler.getNormPriority()` shall be set to

```

1 ((PriorityScheduler.getMaxPriority() -
2  PriorityScheduler.getMinPriority()) / 3) +
3  PriorityScheduler.getMinPriority()

```

14. Hardware priorities, where supported, have values above the base scheduler's priority range (see Section 12.3.4).

6.3.2.2 Dispatching

The execution scheduling semantics described in this section are defined in terms of a conceptual model that contains a set of queues of schedulables that are eligible for execution. There is, conceptually, one queue for each priority on each processor. No implementation structures are necessarily implied by the use of this conceptual model. It is assumed that no time elapses during operations described using this model, and therefore no simultaneous operations are possible.

The RTSJ dispatching model specifies its dispatching rules for the default priority scheduler.

1. A **Schedulable** can become a running schedulable only when it is ready and one of the processors in its requested affinity is available.
2. When two schedulables have different active priorities and request the same processor, the schedulable with the higher active priority will always execute

- in preference to the schedulable with the lower value when both are eligible for execution.
3. Processors are allocated to schedulables based on each schedulable's active priority and their associated affinity.
 4. Schedulable dispatching is the process by which one ready schedulable is selected for execution on a processor. This selection is done at certain points during the execution of a schedulable called *schedulable dispatching points*.
 5. A schedulable reaches a *schedulable dispatching point* whenever it becomes blocked, when it terminates, or when a higher priority schedulable becomes ready for execution on its processor. That is, a schedulable that is executing will continue to execute until it either blocks, terminates or is preempted by a higher-priority schedulable.
 6. The dispatching policy is specified in terms of ready queues and schedulable states. The ready queues are purely conceptual; there is no requirement that such lists physically exist in an implementation. A ready queue is an ordered list of ready schedulable objects. The first position in a queue is called the head of the queue, and the last position is called the tail of the queue.
 7. A schedulable is ready when it is in a ready queue, or when it is running. Each processor has one ready queue for each priority value. At any instant, each ready queue of a processor contains exactly the set of schedulables of that priority that are ready for execution on that processor, but are not running on any processor; that is, those schedulables that are ready, are not running on any processor, and can be executed using that processor.
 8. A schedulable can be on the ready queues of more than one processor.
 9. Each processor has one running schedulable, which is the schedulable currently being executed by that processor. Whenever a schedulable running on a processor reaches a schedulable dispatching point, a new schedulable object is selected to run on that processor. The schedulable selected is the one at the head of the highest priority nonempty ready queue for that processor; this schedulable is then removed from all ready queues to which it belongs.
 10. In a multiprocessor system, a schedulable can be on the ready queues of more than one processor. At the extreme, when several processors share the same set of ready schedulables, the contents of their ready queues are identical, and so they can be viewed as sharing one ready queue, and can be implemented that way. Thus, the dispatching model covers multiprocessors where dispatching is implemented using a single ready queue, as well as those with separate dispatching domains.
 11. The dispatching mechanism must allow the preemption of the execution of schedulables and Java threads with a bounded delay at a point not governed by the preempted object. The bound on this delay may be implementation-

defined, and could be the time to the next point in execution that the heap is in a consistent state or some similar restriction. The implementation should document this bound.

12. A schedulable that is preempted by a higher priority schedulable is placed in the queue for its active priority, at a position determined by the implementation. The implementation must document the algorithm used for such placement. It is recommended that a preempted schedulable be placed at the front of the appropriate queue.
13. A realtime thread that performs a `yield()` is placed at the tail of the queues (dictated by its affinity) for its active priority level.
14. A blocked schedulable that becomes eligible for execution is added to the tail of the queues (dictated by its affinity) for that priority. This behavior also applies to the initial release of a schedulable.
15. A schedulable whose active priority is raised as a result of explicitly setting its base priority (through the `PriorityParameters` `setPriority()` method, the `RealtimeThread` `setSchedulingParameters()` method, or `Thread`'s `setPriority()` method) is added to the tail of the queues (dictated by its affinity) for its new priority level.
16. Queuing when priorities are adjusted by priority inversion avoidance algorithms is governed by semantics specified in the *Synchronization* chapter.

6.3.2.3 Parameter Values

The scheduler uses the values contained in the different parameter objects associated with a schedulable to control the behavior of the schedulable. The scheduler determines what values are valid for the schedulables it manages, which defaults apply and how changes to parameter values are acted upon by the scheduler. Invalid parameter values result in exceptions, as documented in the relevant classes and methods.

1. The default values for the base scheduler are as follows.
 - (a) Scheduling parameters are copied from the creating schedulable when possible; when the creating schedulable does not have scheduling parameters, the default is an instance of the default priority parameters value.
 - (b) Release parameters default to an instance of the default aperiodic parameters (see `AperiodicParameters`).
 - (c) Memory parameters default to `null` which signifies that memory allocation by the schedulable is not constrained by the scheduler.
 - (d) The default scheduling parameter values for parameter objects created by a schedulable controlled by the base scheduler are given by the following table (see `FirstInFirstOutScheduler`).

Attribute	Default Value
<i>Priority parameters</i> priority	norm priority
<i>Importance parameters</i> importance	No default. A value must be supplied.

2. All numeric or **RelativeTime** attributes in parameter values must be greater than or equal to zero.
3. Values of period must be greater than zero.
4. Deadline values in **ReleaseParameters** objects must be less than or equal to their period values (where applicable), but the deadline may be greater than the minimum interarrival time in a **SporadicParameters** object.
5. Changes to scheduling, release, memory, and processing group parameters (by methods on the schedulables bound to the parameters or by altering the parameter objects themselves) have the following effects.
 - (a) They potentially modify the behavior of the scheduler with regard to those schedulables. When such changes in behavior take effect depends on the parameter in question, and the type of schedulable, as described below.
6. When changes to a parameter type—scheduling, release, memory, and processing group—take effect depends on the parameter type.
 - (a) Changes to scheduling parameters take effect immediately except when constrained by priority inversion avoidance algorithms.
 - (b) Changes to release parameters depend on the parameter being changed, the type of release parameter object and the type of schedulable:
 - i. changes to the deadline and the deadline miss handler take effect at each release event as follows: when the i_{th} release event occurred at a time t_i , then the i^{th} deadline is the time $t_i + D_i$, where D_i is the value of the deadline stored in the schedulable's release parameters object at the time t_i . When a deadline miss occurs then it is the deadline miss handler that was installed in the schedulable's release parameters at time t_i that is released;
 - ii. changes to cost and the cost overrun handler take effect immediately;
 - iii. changes to the period and start time values in **PeriodicParameters** objects are described in “Release of realtime Threads” below;
 - iv. changes to the additional values in **AperiodicParameters** objects and **SporadicParameters** are described, respectively, in “Aperiodic Release Control” and “Sporadic Release Control”, below; and
 - v. changes to the type of release parameters object generally take effect after completion, except as documented in the following sections.

- (c) Changes to memory parameters take effect immediately.
- (d) Changes to processing group parameters take effect as described in “Processing Groups” below.
- (e) Changes to the scheduler responsible for a schedulable object take effect at completion.

6.3.2.4 Cost Monitoring and Cost Enforcement

The cost of a schedulable is defined by the value returned by invoking the `getCost` method of the schedulable’s release parameters object. When a schedulable is initially released its current CPU consumption is zero and as the schedulable executes, the current CPU consumption increases. For cost monitoring, an implementation must conform to the following requirements.

1. If, at any time, due to either execution of the schedulable or a change in the schedulable’s cost, the current CPU consumption becomes greater than, or equal to, the current cost of the schedulable, then a cost overrun is triggered.
2. The implementation is required to document the granularity at which the current CPU consumption is updated.
3. When a cost overrun is triggered, the cost overrun handler associated with the `Schedulable`, if any, is released. No further action is taken.
4. The current CPU consumption is reset to zero when the schedulable is next released (i.e. it moves from the blocked-for-release-event state to the eligible-for-execution state).

When cost enforcement is supported, an implementation must conform to the following requirements.

1. When a cost overrun is triggered, in addition to releasing any cost overrun handler, the following actions must be performed.
 - (a) When the most recent release of the schedulable is the i^{th} release, and the $i + 1$ release event has not yet occurred, the following must hold.
 - i. When the state of the schedulable is either executing or eligible-for-execution, the schedulable is placed into the state blocked-by-cost-overrun. There may be a bounded delay between the time at which a cost overrun occurs and the time at which the schedulable becomes blocked-by-cost-overrun.
 - ii. Otherwise, the schedulable must have been blocked for a reason other than blocked-by-cost-overrun. In this case, the state change to blocked-by-cost-overrun is left pending; when the blocking condition for the schedulable is removed, then its state changes to blocked-by-cost-overrun. There may be a bounded delay between the time at which the blocking condition is removed and the time at which the schedulable becomes blocked-by-cost-overrun.

- (b) When the most recent release of the schedulable is the i^{th} release, and the $i + 1$ release event has occurred, the current CPU consumption is set to zero, the schedulable remains in its current state and the cost monitoring system considers the most recent release to now be the $i + 1$ release.
- 2. When the i^{th} release event occurs for a schedulable, the action taken depends on the state of the schedulable.
 - (a) When the schedulable is blocked-by-cost-overflow then the cost monitoring system considers the most recent release to be the i^{th} release, the current CPU consumption is set to zero and the schedulable is made eligible for execution;
 - (b) When the schedulable is blocked for a reason other than blocked-by-cost-overflow then
 - i. when there is a pending state change to blocked-by-cost-overflow then the pending state change is removed, the cost monitoring system considers the most recent release to be the i^{th} release, the current CPU consumption is set to zero, and the schedulable remains in its current blocked state;
 - ii. otherwise, no cost monitoring action occurs.
 - (c) When the schedulable is not blocked, no cost monitoring action occurs.
- 3. When the i^{th} release of a schedulable completes, and the cost monitoring system considers the most recent release to be the i^{th} release, then the current CPU consumption is set to zero and the cost monitoring system considers the most recent release to be the $i + 1$ release. Otherwise, no cost monitoring action occurs.
- 4. Changes to the cost parameter take effect immediately.
 - (a) When the new cost is less than or equal to the current CPU consumption, and the old cost was greater than the current CPU consumption, then a cost overflow is triggered.
 - (b) When the new cost is greater than the current CPU consumption,
 - i. in the case that the schedulable is blocked-by-cost-overflow, the schedulable is made eligible for execution;
 - ii. in the case that the schedulable is blocked for a reason other than blocked-by-cost-overflow and there is a pending state change to blocked-by-cost-overflow, the pending state change is removed;
 - iii. in all other cases, no cost monitoring action occurs.
- 5. The state of the cost monitoring system for a schedulable can be *reset* by the scheduler (see 6.3.2.5 in the **Release of a Realtime Thread** section, below). When the most recent release of the schedulable is considered to be the m^{th} release and the most recent release event for the schedulable was the n^{th} release event (where $n > m$), a reset causes the cost monitoring system to

consider the most recent release to be the n^{th} release, and to zero the current CPU consumption.

6.3.2.5 Release of a Realtime Thread

The repeated release of a realtime thread is achieved by executing in a loop and invoking the `RealtimeThread.waitForNextRelease`¹ methods, or its interruptible equivalent `RealtimeThread.waitForNextReleaseInterruptible`) within that loop. For simplicity, unless otherwise stated, the semantics in this section apply to both forms of this method.

1. A realtime thread's release characteristics are determined by the following:
 - (a) the invocation of the realtime thread's `start` method and the value of its phasing policy parameter (if applicable);
 - (b) the action of the `RealtimeThread` methods `waitForNextRelease`, `schedule`, and `deschedule`;
 - (c) the occurrence of deadline misses and whether or not a miss handler is installed; and
 - (d) whether the passing of time generates periodic release events or calls to the `release` method generates aperiodic release events.
2. The *initial release event* depends on the type of release parameters given the realtime thread:
 - (a) for a realtime thread with periodic parameters, the *initial release event* occurs in response to the invocation of its `start` method in accordance with the start time specified in its release parameters and its assigned phasing policy—see `PeriodicParameters` and `PhasingPolicy`;
 - (b) For a realtime thread with aperiodic parameters, the *initial release event* occurs immediately in response to the invocation of its `start` method.
3. Changes to the start time in a realtime thread's `PeriodicParameters` object only have an effect on its initial release time. Consequently, when a `PeriodicParameters` object is bound to multiple realtime threads, a change in the start time may affect all, some or none, of those threads, depending on whether or not `start` has been invoked on them.
4. When subsequent release events occur also depends on the type of release parameters given to the realtime thread:
 - (a) for periodic realtime threads, each period (and hence each release) falls due, except as described below (in 6d), at regular intervals such that when the i^{th} release event occurred at a time t_i , the $i + 1$ release event occurs at the time $t_i + T_i$, where T_i is the value of the period stored in the realtime thread's `PeriodicParameters` object at the time t_i ;

¹The method `RealtimeThread.waitForNextPeriod` has been replaced by `RealtimeThread.waitForNextRelease` as of RTSJ 2.0. The same goes for its interruptible equivalent.

- (b) for aperiodic realtime threads, a release occurs with each call of the release method, except as described below (in 6d); and
 - (c) for sporadic realtime threads, a release occurs with each call of the release method, except, as described below (in 6d), when additional regulation is required to enforce MIT as defined in *Sporadic Release Control* below.
5. Each release of an aperiodic realtime thread is an arrival.
- (a) When the thread has release parameters of type **AperiodicParameters**, then the arrival may become a release event for the thread according to the semantics given in “Aperiodic Release Control” below.
 - (b) When the thread has release parameters of type **SporadicParameters**, then the arrival may become a release event for the thread according to the semantics given in “Sporadic Release Control” below.
 - (c) When the thread has release parameters of a type other than **SporadicParameters** then the arrival is a release event, and the arrival-time is the release event time.
6. The implementation should behave effectively as if the following state variables were added to a realtime thread’s state,
- boolean **descheduled**,
integer **pendingReleases**,
integer **missCount**, and
boolean **lastReturn**;
- and manipulated by the actions as described below.
- (a) Initially
 - descheduled** = false,
 - pendingReleases** = 0,
 - missCount** = 0, and
 - lastReturn** = true.
 - (b) When the realtime thread’s **deschedule** method is invoked: set the value of **descheduled** to true. When **descheduled** is true, the realtime thread is said to be *descheduled*.
 - (c) When the realtime thread’s **schedule** method is invoked: set the value of **descheduled** to false; then when the thread is blocked-for-release-event, set the value of **pendingReleases** and **missCount** to zero, and tell the cost monitoring and enforcement system to reset for this thread.
 - (d) A realtime thread that has been descheduled and is blocked-for-release-event will not receive any further release events until after it has been rescheduled by a call to **schedule**; this means that no deadline misses can occur until the thread has been rescheduled.
 - (e) When each release event occurs
 - i. when the state of the realtime thread is blocked-for-release-event (that is, it is waiting in **waitForNextRelease**) and the thread is desched-

- ii. when the state is blocked-for-release-event and the thread is scheduled, increment the value of `pendingReleases`, inform cost monitoring and enforcement that the next release event has occurred, and notify the thread to make it eligible for execution;
 - iii. otherwise when the thread is in a release, increment the value of `pendingReleases`, and inform cost monitoring and enforcement that the next release event has occurred.
 - (f) On each deadline miss, there are two cases:
 - i. When the realtime thread has a deadline miss handler, set the value of `descheduled` to true, atomically release the handler with its `fireCount` increased by the value of `missCount + 1`, and zero `missCount`;
 - ii. Otherwise, add one to the `missCount` value.
 - (g) When the `waitForNextRelease` method is invoked by the current realtime thread there are three possible behaviors depending on the value of `missCount` and `lastReturn`.
 - i. When `missCount` is zero, apply any pending parameter changes, inform cost monitoring and enforcement of completion, and then wait while `descheduled` is true, or `pendingReleases` is zero. Then set the `lastReturn` value to true, decrement `pendingReleases`, and return true.
 - ii. When `missCount` is greater than zero and the `lastReturn` value is false, completion occurs: decrement the `missCount` value; then apply any pending parameter changes, decrement `pendingReleases`, inform cost monitoring and enforcement the realtime thread has completed and return false;
 - iii. Otherwise, when `missCount` is greater than zero and the `lastReturn` value is true, decrement the `missCount` value and set the `lastReturn` value to false and return false.
7. An invocation of the `waitForNextRelease` method with release parameters where `ReleaseParameters.isRousable` return true behaves as described above with the following differences.
- (a) When the invocation commences with an instance of `AsynchronouslyInterruptedException` (AIE) is pending on the realtime thread, then the invocation immediately completes abruptly by throwing that pending instance as an `InterruptedException`. When this occurs, the most recent release has not completed. When the pending instance is the generic AIE instance, then the interrupt state of the realtime thread is cleared.
 - (b) When an instance of AIE becomes pending on the realtime thread while it is blocked-for-release-event, and the realtime thread is descheduled,

then the AIE remains pending until the realtime thread is no longer descheduled. The associated reschedule acts as a release event. Execution then continues as in 7d where the time value used as t_{int} is the time at which the schedulable was rescheduled.

- (c) When an instance of AIE becomes pending on the realtime thread while it is blocked-for-release-event and it is not descheduled, then this acts as a release event. Execution then continues as in 7d, where the time value used as t_{int} is the time at which the AIE becomes pending.
- (d)
 - i. The realtime thread is made eligible for execution.
 - ii. Upon execution, the invocation completes abruptly by throwing the pending AIE instance as an `InterruptedException`. When the pending instance is the generic AIE instance then the interrupt state of the realtime thread is cleared.
 - iii. The deadline associated with this release is the time $t_{int} + D_{int}$, where D_{int} is the value of the deadline stored in the realtime thread's release parameters object at the time t_{int} .
 - iv. The next release time for the realtime thread will be $t_{int} + T_{int}$, where T_{int} is the value of the period stored in the realtime thread's release parameters object at the time t_{int} .
 - v. Cost monitoring and enforcement is informed of the release event.

When the thrown AIE instance is caught, the AIE becomes pending again (as per the usual semantics for AIE) until it is explicitly cleared.

- 8. Changes to release parameter types are treated as a pseudo RESTART of the realtime thread and
 - (a) any old pending releases are cleared
 - (b) any old arrival queue is flushed
 - (c) any outstanding call to deschedule is cleared
 - (d) any outstanding deadline misses are cleared

The effect on the thread falls into one of four main cases.

- (a) When the realtime thread is not waiting for next release event and is not descheduled,
 - i. there is no effect until the end of current release, and
 - ii. when the change occurs, it is a pseudo restart of the thread, i.e., when the new parameters are aperiodic, the release is immediate and when the parameters are periodic, the periodic start time algorithm is used.
- (b) When the realtime thread is not waiting for next release event, but there is an outstanding descheduled,
 - i. there is an immediate "schedule" of the thread,
 - ii. there is no further effect until end of current release, and

- iii. when change occurs, it is a pseudo restart of the thread, i.e., when new parameters are aperiodic, the release is immediate, and when new parameters are periodic, the periodic start time algorithm is used.
- (c) When the realtime thread is waiting for next release event, is not descheduled, and the release parameter type is changed,
 - i. from Periodic to Aperiodic, at the next periodic release event occurs, the thread becomes aperiodic with an immediate release, or
 - ii. from Aperiodic to Periodic, there is an immediate pseudo restart of the thread using the periodic start time algorithm.
- (d) When the realtime thread is waiting for the next release event and the type of release parameters is changed, but there is an outstanding descheduled,
 - i. the change is from Periodic to Aperiodic, there is an immediate “schedule” of the thread, and when the next periodic release event occurs, the thread becomes aperiodic with an immediate release, or
 - ii. the change is from Aperiodic to Periodic, there is an immediate “schedule” of the thread and there is an immediate pseudo restart of the thread using the periodic start time algorithm.

6.3.2.5.1 UML Diagrams for Realtime Thread Releases The three UML diagrams in Figures 6.1, 6.2, and 6.3, are provided to illustrate the foregoing rules for releasing realtime threads. The first two figures are for a thread without a deadline miss handler. The first is a UML sequence diagram of some example Realtime Thread releases. The second is a UML state chart of the release process for a realtime thread. The third is a UML state chart of the release process for a realtime thread with a deadline miss handler.

In Figure 6.1, a yellow background marks the execution of a normal release, an orange background marks the execution of a miss handler, and a red background marks the execution of a missed release. Both the miss handler and all missed releases are eligible to run as soon as the previous release is finish. A normal release, which encounters a deadline miss during its execution is not complete until its miss handler completes.

In the other two figures, a yellow background marks releases and a pink background marks blocked states. There are three release states: normal release, miss handler, and missed release. They can only be left by a call to `waitForNextRelease` or its equivalent. The miss handler state is part of a normal release that misses its deadline during the release. There are two blocked-for-release-event states: blocked for normal release and blocked for missed release. It is only in these states that descheduling can occur, because only completion occurs upon their entry. In addi-

Figure 6.2: A State Chart for a Realtime Thread without a Deadline Miss Handler

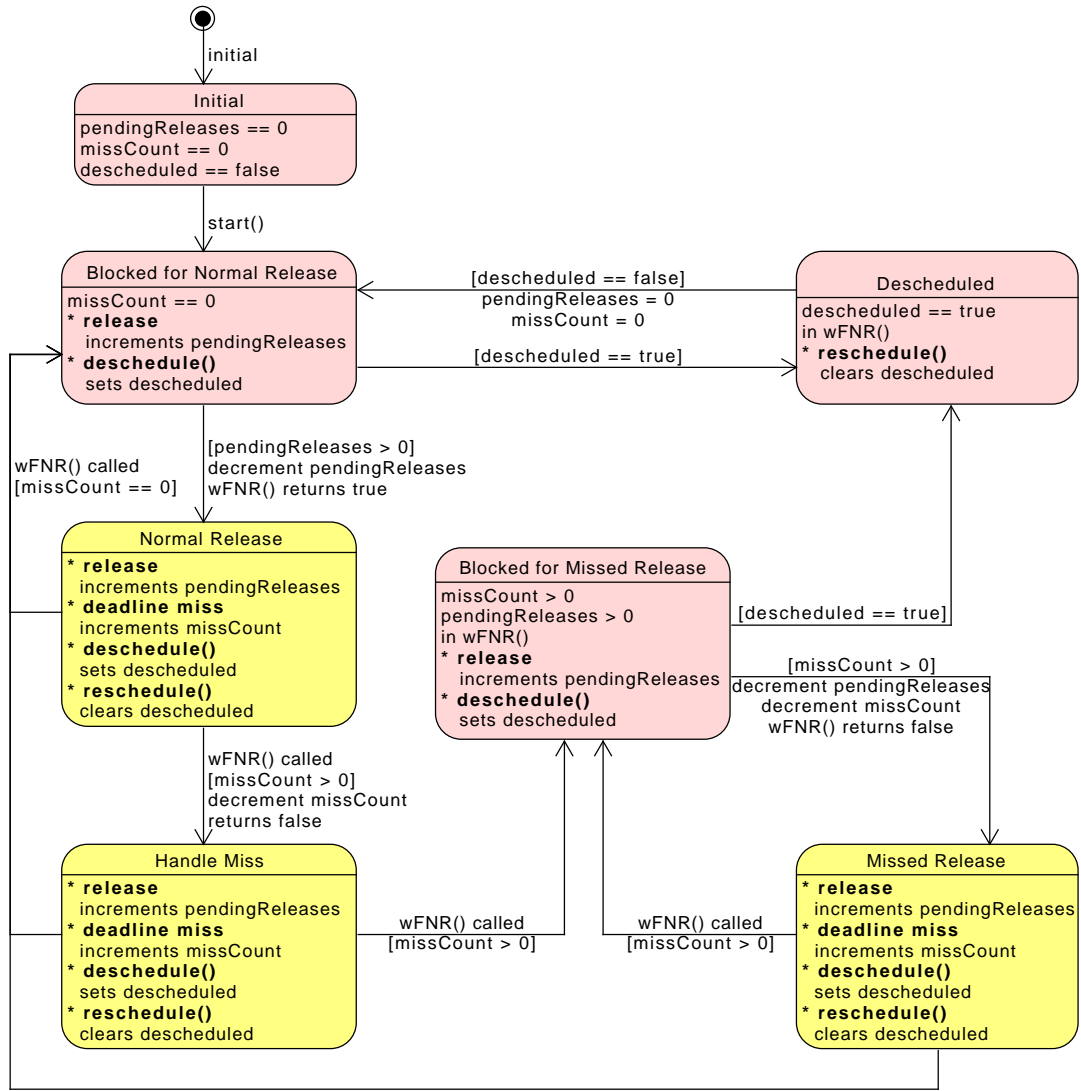
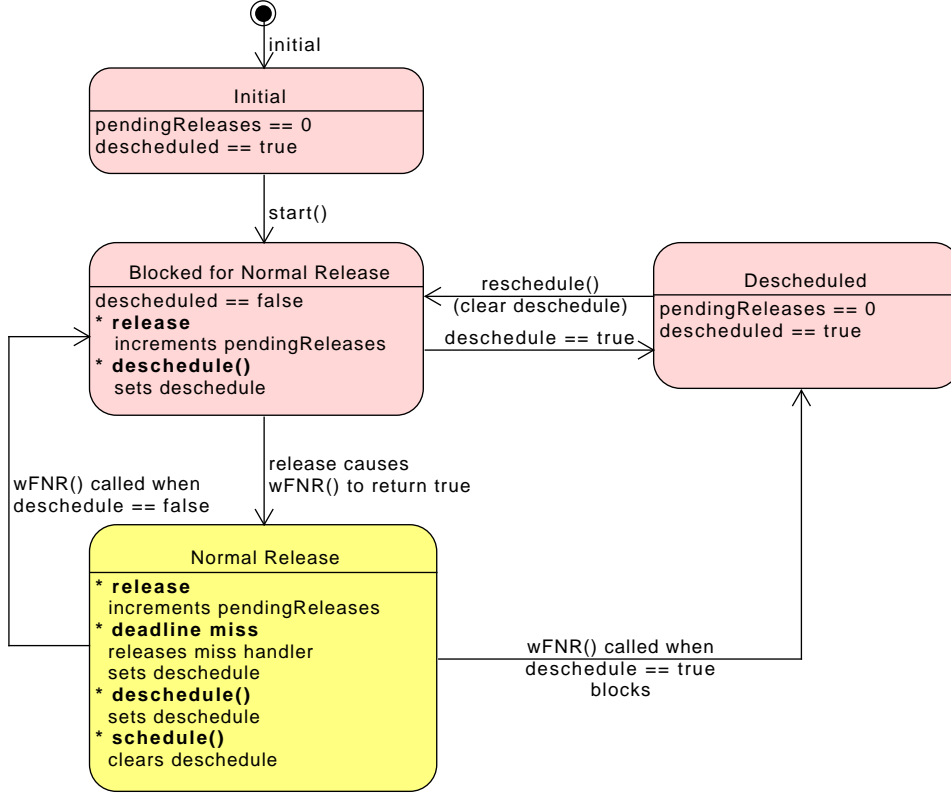


Figure 6.3: A State Chart for a Realtime Thread with a Deadline Miss Handler



tion, the blocked for missed release is a ephemeral state, since the deadline miss has already occurred before the state is entered, so state is left immediately. It is there to enable all actions that occur on completion.

6.3.2.6 Aperiodic Release Control

Aperiodic schedulables are released in response to events occurring, such as the starting of a realtime thread, the calling of the `release` method of a realtime thread, or the firing of an associated asynchronous event for an asynchronous event handler. The occurrence of these events, each of which is a potential release event, is termed an *arrival*, and the time that they occur is termed the *arrival time*.

The base scheduler behaves effectively as if it maintained a queue, called the arrival time queue, for each aperiodic schedulable object. This queue maintains information related to each release event (including any parameters passed with the

release mechanism) from its “arrival” time until the associated release completes, or another release event occurs — whichever is later. When an arrival is accepted into the arrival time queue, then it is a release event and the time of the release event is the arrival time. The initial size of this queue is an attribute of the schedulable’s aperiodic parameters, and is set when an aperiodic parameter object is first associated with the schedulable. Over time the queue may become full and its behavior in this situation is determined by the queue overflow policy specified in the schedulable’s aperiodic parameters. There are four overflow policies defined:

Policy	Action on Overflow
IGNORE	Silently ignore the arrival. The arrival is not accepted, no release event occurs, and, when the arrival was caused programmatically (such as by invoking <code>fire</code> on an asynchronous event), the caller is not informed that the arrival has been ignored.
EXCEPT	Throw an <code>ArrivalTimeQueueOverflowException</code> . The arrival is not accepted, and no release event occurs, but when the arrival was caused programmatically, the caller will have <code>ArrivalTimeQueueOverflowException</code> thrown.
REPLACE	The arrival is not accepted and no release event occurs. When the completion associated with the last release event in the queue has not yet occurred, and the deadline has not been missed, the release event time for that release event is replaced with the arrival time of the new arrival and any associated parameters overwritten. This will alter the deadline for that release event. When the completion associated with the last release event has occurred, or the deadline has already been missed, the behavior of the REPLACE policy is equivalent to the IGNORE policy.
SAVE	Behave effectively as if the queue were expanded as necessary to accommodate the new arrival. The arrival is accepted and a release event occurs.

Under the SAVE policy the queue can grow and shrink over time.

Changes to the queue overflow policy take effect immediately. When an arrival occurs and the queue is full, the policy applied is the policy as defined at that time.

6.3.2.7 Sporadic Release Control

Sporadic parameters include a minimum interarrival time, MIT, that characterizes the expected frequency of releases. When an arrival is accepted implementation

behaves as if it calculates the earliest time at which the next arrival could be accepted, by adding the current MIT to the arrival time of this accepted arrival. The scheduler guarantees that each sporadic schedulable it manages, is released at most once in any MIT. It implements two mechanisms for enforcing this rule:

1. *Arrival-time regulation* controls the work-load by considering the time between arrivals. When a new arrival occurs earlier than the expected next arrival time then a MIT violation has occurred, and the scheduler acts to prevent a release from occurring that would break the “one release per MIT” guarantee. Three arrival-time MIT-violation policies are supported:

Policy	Action on Violation
IGNORE	Silently ignore the violating arrival. The arrival is not accepted, no release event occurs, and, when the arrival was caused programmatically (such as by invoking <code>fire</code> on an asynchronous event), the caller is not informed that the arrival has been ignored.
EXCEPT	Throw a <code>MITViolationException</code> . The arrival is not accepted, and no release event occurs, but when the arrival was caused programmatically, the caller will have <code>MITViolationException</code> thrown.
REPLACE	The arrival is not accepted and no release event occurs. When the completion associated with the last release event in the queue has not yet occurred, and the deadline has not been missed, then the release event time for that release event is replaced with the arrival time of the new arrival and any associated parameters overwritten. This will alter the deadline for that release event. When the completion associated with the last release event has occurred, or the deadline has already been missed, the behavior of the REPLACE policy is equivalent to the IGNORE policy.

2. *Execution-time regulation* occurs when the MIT violation policy SAVE is in effect. Under this policy all arrivals are accepted, but the scheduler behaves effectively as if released schedulable objects were further constrained by a scheduling policy that restricts execution to at most one release per MIT. This policy is only able to delay the effective release of a schedulable. The deadline of each release event is always set relative to its arrival time. This policy may not schedule the effective release of an async event handler until after its deadline has passed. In this case the deadline miss handler is released at the deadline time even though the related async event has not yet reached

its effective release.

The SAVE policy makes no direct use of the next expected arrival time, but it maintains the value in case the MIT violation policy is changed from SAVE to one of the arrival-time regulation policies.

The *effective release time* of a release event i is the earliest time that the handler can be released in response to that release event. It is determined for each release event based on the MIT policy in force at the release event time:

1. For IGNORE, EXCEPT and REPLACE the effective release time is the release event time.
2. For SAVE the effective release time of release event i is the effective release time of release event $i-1$ plus the current value of the MIT.

The scheduler will delay the release associated with the release event at the head of the arrival time queue until the current time is greater than or equal to the effective release time of that release event.

Changes to minimum interarrival time and the MIT violation policy take effect immediately, but only affect the next expected arrival time, and effective release time, for release events that occur after the change.

6.3.2.8 Release Control for Asynchronous Event Handlers

Asynchronous event handlers can be associated with one or more asynchronous events. When an asynchronous event is fired, all handlers associated with it are released, according to the semantics below:

1. Each firing of an associated asynchronous event is an arrival. If the handler has release parameters of type **AperiodicParameters**, then the arrival may become a release event for the handler, according to the semantics given in “Aperiodic Release Control” above. When the handler has release parameters of type **SporadicParameters**, the arrival may become a release event for the handler, according to the semantics given in “Sporadic Release Control” above. When the handler has release parameters of a type other than **SporadicParameters**, the arrival is a release event, and the arrival-time is the release event time.
2. For each release event that occurs for a handler, an entry is made in the arrival-time queue and the handler’s **fireCount** is incremented by one.
3. Initially a handler is considered to be blocked-for-release-event and its **fireCount** is zero.
4. Releases of a handler are serialized by having its **handleAsyncEvent** method invoked repeatedly while its **fireCount** is greater than zero:
 - (a) Before invoking **handleAsyncEvent**, the **fireCount** is decremented and the front entry (when still present) removed from the arrival-time queue.
 - (b) Each invocation of **handleAsyncEvent**, in this way, is a release.

- (c) The return from `handleAsyncEvent` is the completion of a release.
 - (d) Processing of any exceptions thrown by `handleAsyncEvent` occurs prior to completion.
5. The deadline for a release is relative to the release event time and determined at the release event time according to the value of the deadline contained in the handler's release parameters. This value does not change, except as described previously for handlers using a REPLACE policy for MIT violation or arrival-time queue overflow.
 6. The application code can directly modify the `fireCount`.
 - (a) The `getAndDecrementPendingFireCount` method decreases the `fireCount` by one (when it is greater than zero), and returns the old value. This removes the front entry from the arrival-time queue but otherwise has no effect on the scheduling of the current schedulable, nor the handler itself. Any data parameter passed with the associated fire request is lost.
 - (b) The `getAndClearPendingFireCount` method is functionally equivalent to invoking `getAndDecrementPendingFireCount` until it returns zero, and returning the original `fireCount` value. Any data parameters passed with the associated fire requests are lost.
 7. The scheduler may delay the invocation of `handleAsyncEvent` to ensure the effective release time honors any restrictions imposed by the MIT violation policy, when applicable, of that release event.
 8. Cost monitoring and enforcement for an asynchronous event handler interacts with release events and completions as previously defined with the added requirement that at the completion of `handleAsyncEvent`, when the `fireCount` is now zero, then the cost monitoring and enforcement system is told to reset for this handler.
 9. The value of `ReleaseParameters.getRousable` controls whether a call to `Schedulable.interrupt` caused a premature release or only affects a running schedulable.
 - (a) When `interrupt` is called on a `Schedulable` and the `Schedulable` is running, the interrupt is marked as pending and as soon as AI code is entered, an AIE is thrown.
 - (b) When `interrupt` is called on a `Schedulable` that is waiting for a release or its start time, the interrupt is marked as pending.
 - (c) Depending on the value of the new `ReleaseParameters` property, start will prematurely complete, i.e., start user code, or simply wait for the start time to occur.
 - (d) Depending on the value of the new `ReleaseParameters` property, the next release of a handler will occur immediately or not, but in both cases an AIE will be pending until the next AI method.

6.3.3 The Round-Robin Scheduler

The round-robin scheduler specified by the RTSJ is a fixed-quantum, fixed-priority priority-preemptive scheduler that interacts predictably with the base scheduler. Quantum expiry may be calculated either from task switch or on a heartbeat. It uses the `PriorityParameters` class for the configuration of schedulable priorities. It may not be present on all systems, but if it is present then it will obey the semantics specified here.

When a schedulable managed by the round-robin scheduler is scheduled, it will run either until it blocks (as on a monitor or for some I/O operation), voluntarily relinquishes the CPU (as for sleep), is priority preempted, or its quantum has elapsed.

The scheduler is not responsible for ensuring that a release, such as an event handler will complete within the quantum. A releases which would run longer than its quantum will be rescheduled at the end of that quantum and before completion when another task with the same priority is ready to run. When this is not the desired behavior, the `FirstInFirstOutScheduler` should be used instead.

Open issue: If present, can the round-robin scheduler manage any schedulable? What about asynchronous event handlers used for interrupts? How do we draw this line? **End of open issue**

6.3.3.1 Priorities

Priorities in the round-robin scheduler are as in the base scheduler, and priority values are numerically equivalent between the two. Schedulables managed by the round-robin scheduler behave as if they are scheduled from the same FIFO queue as schedulables managed by the base scheduler of the same numeric priority, except that they will consume no more than one quantum of execution time before being moved to the tail of the queue. Implementations are permitted to use a single, shared queue for this purpose.

If the round-robin scheduler is present, its priorities will have the same properties as the base scheduler, except for the following.

1. The round-robin scheduler must support at least one priority, and may support an arbitrarily large number of priorities.
2. All round-robin priorities must be greater than 10, and they must include all integers from the round-robin scheduler's `getMinPriority()` value to its `getMaxPriority()` value, inclusive.
3. The round-robin scheduler does not use the `importance` value in the `ImportanceParameters` subclass of `PriorityParameters`.
4. `RoundRobinScheduler.getNormPriority()` shall be set to

1 $((\text{RoundRobinScheduler.getMaxPriority()} -$

```

2 RoundRobinScheduler.getMinPriority()) / 3) +
3 RoundRobinScheduler.getMinPriority()

```

The round-robin scheduler may provide priorities strictly lower than the base scheduler or a set of priorities partially or entirely overlapping with the priorities provided by the base scheduler.

6.3.4 Managing Groups of Schedulables

Conventional Java provides the class `ThreadGroup` to manage groups of threads. Only minimal functionality is provided: limiting priority, setting daemon status, and interrupting a group of threads at once. RTSJ extends this concept in two ways: limiting CPU affinity through the `Affinity` class and providing subclasses for managing `Schedulables`.

6.3.4.1 Scheduling Groups

The `SchedulingGroup` subclass of `ThreadGroup` provides a means of limiting the importance or priority, the affinity, and scheduler of instance of `Schedulable`. The `setMaxPriority` method on `ThreadGroup` only pertains to tasks scheduled in the conventional Java range (1–10), but not for tasks scheduled with a realtime scheduler. To ensure that this works and that conventional thread groups must not need to be scope aware, an implementation must enforce several restrictions:

1. only tasks in a scheduling group may use a realtime scheduler,
2. instances of `Schedulable` may only be created in a scheduling group,
3. the root `ThreadGroup` instance must be an instance of `SchedulingGroup`,
4. the `ThreadGroup` instance of the initial thread must be an instance of `SchedulingGroup`,
5. an instance of `SchedulingGroup` may not have a parent that is not an instance of `SchedulingGroup`, and
6. all `ThreadGroup` instance children of `SchedulingGroup` allocated in a `ScopedMemory` must be instances of `SchedulingGroup`.

Furthermore, the enumeration methods on a scheduling group do not return any members in a `ScopedMemory` that not assignable from `this`; for processing these a visitor must be used.

6.3.4.2 Processing Groups

A processing group is defined by an instance of the `ProcessingGroup` subclass of `SchedulingGroup` and each schedulable that is bound to that parameter object is called a *member* of that processing group. Processing groups are only functional

in a system that implements processing group enforcement. A processing group instance acts as a proxy for its members, but enforcement does have an effect on the execution of member threads.

6.3.4.2.1 Definitions for Processing Groups

The *enforced priority* of a schedulable is a priority with no execution eligibility.

6.3.4.2.2 Semantics for Processing Groups

1. The deadline of a processing group is defined by the value returned by invoking the `getDeadline` method of the processing group object.
2. A deadline miss for the processing group is triggered when any member of the processing group consumes CPU time at a time greater than the deadline for the most recent release of the processing group.
3. When a processing group misses a deadline:
 - (a) when the processing group has a miss handler, it is released for execution,
 - (b) otherwise, the processing group has no miss handler, no action is taken.
4. The cost of a processing group is defined by the value returned by invoking the `getCost` method of the processing group object.
5. When a processing group is initially released, its current CPU consumption is zero and as the members of the processing group execute, the current CPU consumption increases. The current CPU consumption is set to zero in response to certain actions as described below.
6. If at any time, due to either execution of the members of the processing group or a change in the group's cost, the current CPU consumption becomes greater than, or equal to, the current cost of the processing group, then a cost overrun is triggered. The implementation is required to document the granularity at which the current CPU consumption is updated.
7. When the affinity of the group contains more than one processor, the granularity enforced is the base granularity times the number of processors in the group's affinity.
8. When a cost overrun is triggered, the cost overrun handler associated with the processing group, if any, is released, and the processing group enters the **enforced state**. For each member of the processing group:
 - (a) the schedulable is placed into the enforced state; and
 - (b) when a schedulable is in the enforced state, the base scheduler schedules that schedulable effectively as if the enforced priority were used in place of the schedulable's base priority.
9. When the release event occurs for a processing group, the action taken depends on the state of the processing group.
 - (a) When the processing group is not in the enforced state, the current CPU

- consumption for the group is set to zero.
- (b) Otherwise, the processing group is in the enforced state. It is removed from the enforced state, the current CPU consumption of the group is set to zero, and each member of the group is removed from the enforced state.
10. Changes to the cost take effect immediately.
- (a) When the new cost is less than or equal to the current CPU consumption, and the old cost was greater than the current CPU consumption, a cost overrun is triggered.
 - (b) When the new cost is greater than the current CPU consumption there are two case:
 - i. when the processing group is enforced, then the processing group behaves as defined in semantic 9;
 - ii. otherwise, no cost monitoring and enforcement action occurs.
11. Changes to other parameters take place as follows:
- (a) **start** can only be changed before the parameters group is started, i.e., before the start time or before the parameter object is associated with any schedulable and changes take effect immediately;
 - (b) **period** can be change at each release, so the next period is set based on the current value of the processing group's period;
 - (c) **deadline** can change at each release, so the next deadline is set based on the current value of the processing group's deadline;
 - (d) **OverrunHandler** can change at each release, so the overrunHandler is set based on the current value of the processing group's overrunHandler; and
 - (e) **MissHandler** can change at each release, so the missHandler is set based on the current value of the processing group's missHandler.
12. Changes to the membership of the processing group take effect immediately.
13. The start time for the processing group may be relative or absolute.
- (a) When the start time is absolute, the processing group behaves effectively as if the initial release time were the start time.
 - (b) When the start time is relative, the initial release time is computed relative to the time **start** or **fire** (as appropriate) is first called for a member of the processing group.

Note, until a processing group starts, its budget cannot be replenished, but its members will be enforced if they exceed the initial budget. Also, once a processing group is started, it behaves effectively as if it continued running continuously until the defining `ProcessingGroup` object is freed.

6.4 Package javax.realtime

6.4.1 Interfaces

6.4.1.1 BoundSchedulable

Interfaces

Schedulable

A marker interface to provide a type safe reference to all schedulables that are bound to a single underlying thread. A **RealtimeThread**² is by definition bound.

6.4.1.2 RealtimeExecutionContext

All RTSJ objects that encapsulate execution. This type includes **Schedulable** and `javax.realtime.device.InterruptServiceRoutine`. It is used by **Affinity** to remove the need to have a reference into the `javax.realtime.device` package.

6.4.1.3 Schedulable

Interfaces

Runnable

Timable

RealtimeExecutionContext

Handlers and other objects can be dispatched by a **Scheduler**³ when they provide a `run()` method and the methods defined below. The **Scheduler**⁴ uses this information to create a suitable context to execute the `run()` method.

6.4.1.3.1 Methods

²Section 5.3.2.2

³Section 6.4.2.11

⁴Section 6.4.2.11

getMemoryParameters

Signature

```
public  
    javax.realtime.MemoryParameters getMemoryParameters()
```

Gets a reference to the [MemoryParameters](#)⁵ object for this schedulable.

Returns

A reference to the current [MemoryParameters](#)⁶ object.

getSchedulingGroup

Signature

```
public  
    javax.realtime.SchedulingGroup getSchedulingGroup()
```

Gets a reference to the [SchedulingGroup](#)⁷ instance of this schedulable.

Returns

A reference to the current [SchedulingGroup](#)⁸ object.

getConfigurationParameters

Signature

```
public  
    javax.realtime.ConfigurationParameters getConfigurationParameters()
```

Gets a reference to the [ConfigurationParameters](#)⁹ object for this schedulable.

Returns

A reference to the associated [ConfigurationParameters](#)¹⁰ object.

getReleaseParameters

Signature

⁵Section [11.4.2.4](#)

⁶Section [11.4.2.4](#)

⁷Section [6.4.2.12](#)

⁸Section [6.4.2.12](#)

⁹Section [5.3.2.1](#)

¹⁰Section [5.3.2.1](#)

```
public  
javax.realtime.ReleaseParameters getReleaseParameters()
```

Gets a reference to the [ReleaseParameters](#)¹¹ object for this schedulable.

Returns

A reference to the current [ReleaseParameters](#)¹² object.

getScheduler

Signature

```
public  
javax.realtime.Scheduler getScheduler()
```

Gets a reference to the [Scheduler](#)¹³ object for this schedulable.

Returns

A reference to the associated [Scheduler](#)¹⁴ object.

getSchedulingParameters

Signature

```
public  
javax.realtime.SchedulingParameters getSchedulingParameters()
```

Gets a reference to the [SchedulingParameters](#)¹⁵ object for this schedulable.

Returns

A reference to the current [SchedulingParameters](#)¹⁶ object.

setMemoryParameters(MemoryParameters)

Signature

```
public  
void setMemoryParameters(MemoryParameters memory)
```

¹¹Section [6.4.2.9](#)

¹²Section [6.4.2.9](#)

¹³Section [6.4.2.11](#)

¹⁴Section [6.4.2.11](#)

¹⁵Section [6.4.2.13](#)

¹⁶Section [6.4.2.13](#)

Sets the memory parameters associated with this instance of **Schedulable**.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable object. See the documentation for the scheduler for details.

Parameters

memory A **MemoryParameters**¹⁷ object which will become the memory parameters associated with **this** after the method call. When **null**, the default value is governed by the associated scheduler (a new object is created when the default value is not **null**). (See **PriorityScheduler**¹⁸.)

Throws

IllegalArgumentException when **memory** is not compatible with the schedulable's scheduler. Also when this schedulable is no-heap and **memory** is located in heap memory.

IllegalAssignmentError when the schedulable cannot hold a reference to **memory**, or when **memory** cannot hold a reference to this schedulable instance.

IllegalStateException when the schedulable's scheduler prohibits this parameter change at this time due to the state of the schedulable.

setReleaseParameters(ReleaseParameters)

Signature

```
public  
void setReleaseParameters(ReleaseParameters release)
```

Sets the release parameters associated with this instance of **Schedulable**.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable. The different properties of the release parameters may take effect at different times. See the documentation for the scheduler for details.

Parameters

release A **ReleaseParameters**¹⁹ object which will become the release parameters associated with this after the method call, and take effect as determined by the associated scheduler. When **null**, the default value is governed by the associated scheduler (a new object is created when the default value is not

¹⁷Section 11.4.2.4

¹⁸Section 6.4.2.7

¹⁹Section 6.4.2.9

`null`). (See [PriorityScheduler](#)²⁰.)

Throws

`IllegalArgumentException` Thrown when `release` is not compatible with the associated scheduler. Also when this schedulable is no-heap and `release` is located in heap memory.

`IllegalAssignmentError` when `this` object cannot hold a reference to `release` or `release` cannot hold a reference to `this`.

`IllegalThreadStateException` when the schedulable's scheduler prohibits the changing of the release parameter at this time due to the state of the schedulable.

setScheduler(Scheduler)

Signature

```
public  
void setScheduler(Scheduler scheduler)
```

Sets the reference to the Scheduler object. The timing of the change must be agreed between the scheduler currently associated with this schedulable, and `scheduler`. If the `Schedulable` is running, its associated `SchedulingParameters` (if any) must be compatible with `scheduler`.

Parameters

scheduler A reference to the scheduler that will manage execution of this schedulable. `Null` is not a permissible value.

Throws

`IllegalArgumentException` Thrown when `scheduler` is `null`, or the schedulable's existing parameter values are not compatible with `scheduler`. Also when this schedulable is no-heap and `scheduler` is located in heap memory.

`IllegalAssignmentError` when the schedulable cannot hold a reference to `scheduler` or the current `Schedulable` is running and its associated `SchedulingParameters` are incompatible with `scheduler`.

`SecurityException` when the caller is not permitted to set the scheduler for this schedulable.

`IllegalThreadStateException` when `scheduler` refuses to accept this schedulable at this time due to the state of the schedulable.

setScheduler(Scheduler, SchedulingParameters, ReleaseParameters, MemoryParameters)

²⁰Section [6.4.2.7](#)

Signature

```
public
void setScheduler(Scheduler scheduler,
                  SchedulingParameters scheduling,
                  ReleaseParameters release,
                  MemoryParameters memoryParameters)
```

Sets the scheduler and associated parameter objects. The timing of the change must be agreed between the scheduler currently associated with this schedulable, and `scheduler`.

Parameters

`scheduler` A reference to the scheduler that will manage the execution of this schedulable. `Null` is not a permissible value.

`scheduling` A reference to the [SchedulingParameters](#)²¹ which will be associated with `this`. When `null`, the default value is governed by `scheduler` (a new object is created when the default value is not `null`). (See [PriorityScheduler](#)²².)

`release` A reference to the [ReleaseParameters](#)²³ which will be associated with `this`. When `null`, the default value is governed by `scheduler` (a new object is created when the default value is not `null`). (See [PriorityScheduler](#)²⁴.)

`memoryParameters` A reference to the [MemoryParameters](#)²⁵ which will be associated with `this`. When `null`, the default value is governed by `scheduler` (a new object is created when the default value is not `null`). (See [PriorityScheduler](#)²⁶.)

Throws

`IllegalArgumentException` Thrown when `scheduler` is `null` or the parameter values are not compatible with `scheduler`. Also thrown when this schedulable is no-heap and `scheduler`, `scheduling` `release`, `memoryParameters`, or `group` is located in heap memory.

`IllegalAssignmentError` when `this` object cannot hold references to all the parameter objects or the parameters cannot hold references to `this`.

`IllegalThreadStateException` when `scheduler` prohibits the changing of

²¹Section [6.4.2.13](#)

²²Section [6.4.2.7](#)

²³Section [6.4.2.9](#)

²⁴Section [6.4.2.7](#)

²⁵Section [11.4.2.4](#)

²⁶Section [6.4.2.7](#)

the scheduler or a parameter at this time due to the state of the schedulable. **SecurityException** when the caller is not permitted to set the scheduler for this schedulable.

setSchedulingParameters(SchedulingParameters)

Signature

```
public  
void setSchedulingParameters(SchedulingParameters scheduling)
```

Sets the scheduling parameters associated with this instance of **Schedulable**.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable. See the documentation for the scheduler for details.

Parameters

scheduling A reference to the **SchedulingParameters**²⁷ object. When **null**, the default value is governed by the associated scheduler (a new object is created when the default value is not **null**). (See **PriorityScheduler**²⁸.)

Throws

IllegalArgumentException Thrown when **scheduling** is not compatible with the associated scheduler. Also when this schedulable is no-heap and **scheduling** is located in heap memory.

IllegalAssignmentError when **this** object cannot hold a reference to **scheduling** or **scheduling** cannot hold a reference to **this**.

IllegalThreadStateException when the schedulable's scheduler prohibits the changing of the scheduling parameter at this time due to the state of the schedulable object.

getMinConsumption(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getMinConsumption(RelativeTime dest)
```

Determine the minimum CPU consumption for this schedulable in any single release. When this method is called on the current schedulable, the CPU con-

²⁷Section 6.4.2.13

²⁸Section 6.4.2.7

sumption of the current release is not considered. When **dest** is **null**, return the minimum consumption in a [RelativeTime](#)²⁹ instance from the current allocation context. When **dest** is not **null**, return the minimum consumption in **dest**

Parameters

dest when not **null** is the object in which to return the result.

Returns

the minimum time consumed in any release.

getMinConsumption

Signature

```
public  
javax.realtime.RelativeTime getMinConsumption()
```

Equivalent to `getMinConsumption(null)`.

Returns

the minimum time consumed in any release.

getMaxConsumption(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getMaxConsumption(RelativeTime dest)
```

Determine the maximum CPU consumption for this schedulable in any single release. When this method is called on the current schedulable, the CPU consumption of the current release is not considered. When **dest** is **null**, return the maximum consumption in a [RelativeTime](#)³⁰ instance from the current allocation context. When **dest** is not **null**, return the maximum consumption in **dest**

Parameters

dest when not **null** is the object in which to return the result.

Returns

the maximum time consumed in any release.

getMaxConsumption

Signature

²⁹Section [9.4.1.3](#)

³⁰Section [9.4.1.3](#)


```
public  
    javax.realtime.RelativeTime getMaxConsumption()
```

Equivalent to `getMaxConsumption(null)`.

Returns

the maximum time consumed in any release.

mayUseHeap

Signature

```
public  
    boolean mayUseHeap()
```

Determine whether or not this `schedulable` may use the heap.

Returns

`true` only when this `Schedulable` may allocate on the heap and may enter the Heap.

interrupt

Signature

```
public  
    void interrupt()
```

Generates the generic `AsynchronouslyInterruptedException`³¹ and targets it at this, and sets the interrupted state to pending. As with `Thread.interrupt()`, blocking operations that are interruptible are interrupted.

awaken

Signature

```
public  
    void awaken()  
    throws IllegalStateException
```

Provides a means for a `Clock`³² to end a sleep.

Throws

³¹Section 8.4.2.1

³²Section 10.4.2.1

`IllegalStateException` when called from user code.

6.4.2 Classes

6.4.2.1 Affinity

Inheritance

`java.lang.Object`
`javafx.realtime.Affinity`

This class is the API for all processor-affinity-related aspects of the RTSJ. It includes a factory that generates `Affinity` objects, and methods that control the default affinity sets used when affinity set inheritance does not apply.

An affinity is a set of processors that can be associated with certain types of tasks. Each `java.lang.Thread` and `RealtimeExecutionContext`³³ can be associated with an affinity. Groups of these can be assigned an affinity through a `java.lang.ThreadGroup`.

Each implementation supports an array of predefined affinity sets. They can be used either to reflect the scheduling arrangement of the underlying OS or they can be used by the system designer to impose defaults for groups of task. A program is only allowed to dynamically create new affinity sets with cardinality of one. This restriction reflects the concern that not all operating systems will support multiprocessor affinity sets.

The processor membership of an affinity set is immutable. The tasks associations of an affinity set are mutable. The processor affinity of a task can be changed by static methods in this class. The internal representation of a set of processors in an `Affinity` instance is not specified, but the representation that is used to communicate with this class is a `BitSet` where each bit corresponds to a logical processor ID. The relationship between logical and physical processors is beyond the scope of this specification, and may change.

The affinity set factory only generates usable `Affinity` instances; i.e., affinity sets that (at least when they are created) can be used with `set(Affinity, RealtimeExecutionContext)`³⁴, `set(Affinity, Thread)`³⁵, and `set(Affinity, ThreadGroup)`³⁶. The factory cannot create an affinity set with more than one processor member, but such affinity sets are supported. They may be internally created by the RTSJ runtime at startup time.

³³Section 6.4.1.2

³⁴Section 6.4.2.1.1

³⁵Section 6.4.2.1.1

³⁶Section 6.4.2.1.1

The set of affinity sets created at startup (the predefined set) is visible through the `getPredefinedAffinities(Affinity[])`³⁷ method. The affinity set factory may be used to create affinity sets with a single processor member at any time. This operation only supports processor members that are available to the JVM at the time of creation.

External changes to the set of processors available to the RTSJ runtime is likely to cause serious trouble ranging from violation of assumptions underlying schedulability analysis to freezing the entire RTSJ runtime, so when a system is capable of such manipulation it should not exercise it on RTSJ processes.

Tasks are subject to both their own processor affinity and that of their thread group. Their processor affinity is governed by the intersection of the thread group's affinity and the schedulable's affinity. The intersection of a thread group's affinity set with the schedulable's affinity set must contain at least one entry. Trying to set a tasks affinity outside its thread group always fails. Trying to setting the affinity of a thread group that does not intersect with the thread group of its tasks will also fail.

Ordinarily, an execution context inherits its creator's affinity set, but

- Java threads do not inherit affinity from `Schedulable`³⁸,
- instance of `AsyncBaseEventHandler`³⁹ that are not bound are not affected, and
- a `Schedulable` does not inherit affinity from Java threads.

When a task does not inherit its creator's affinity set, its initial affinity set is set to all processors and is thus only limited by its thread group.

There is no public constructor for this class. All instances must be created by the factory method (`generate`).

6.4.2.1.1 Methods

getPredefinedAffinitiesCount

Signature

```
public static final
int getPredefinedAffinitiesCount()
```

³⁷Section 6.4.2.1.1

³⁸Section 6.4.1.3

³⁹Section 8.4.3.3

Return the minimum array size required to store references to all the predefined processor affinity sets.

Returns

The minimum array size required to store references to all the predefined affinity sets.

getPredefinedAffinities

Signature

```
public static final  
    javax.realtime.Affinity[] getPredefinedAffinities()
```

Equivalent to invoking `getPredefinedAffinitySets(null)`.

Returns

an array of the pre-defined affinity sets.

getPredefinedAffinities(Affinity)

Signature

```
public static final  
    javax.realtime.Affinity[] getPredefinedAffinities(javax.realtime.Affinity[] dest)
```

Return an array containing all affinity sets that were predefined by the Java runtime.

Parameters

dest The destination array, or `null`.

Throws

`IllegalArgumentException` when **dest** is not large enough.

Returns

dest or a newly created array when **dest** is `null`, populated with references to the pre-defined affinity sets.

When **dest** has excess entries, they are filled with `null`.

isSetAffinitySupported

Signature

```
public static final  
    boolean isSetAffinitySupported()
```

Determine whether or not affinity control is supported.

Returns

true when the `set(Affinity, Thread)`⁴⁰ family of methods is supported.

generate(BitSet)

Signature

```
public static final  
    javax.realtime.Affinity generate(BitSet bitSet)
```

Returns an Affinity set with the affinity `BitSet bitSet` and no associations.

Platforms that support specific affinity sets will register those `Affinity` instances with `Affinity`⁴¹. They appear in the arrays returned by `getPredefinedAffinities()`⁴² and `getPredefinedAffinities(Affinity[])`⁴³.

Parameters

`bitSet` The `BitSet` associated with the generated `Affinity`.

Throws

`NullPointerException` when `bitSet` is null.

`IllegalArgumentException` when `bitSet` does not refer to a valid set of processors, where “valid” is defined as the bitset from a pre-defined affinity set, or a bitset of cardinality one containing a processor from the set returned by `getAvailableProcessors()`. The definition of “valid set of processors” is system dependent; however, every set consisting of one valid processor makes up a valid bit set, and every bit set correspond to a pre-defined affinity set is valid.

Returns

The resulting `Affinity`.

getAvailableProcessors

Signature

```
public static final  
    java.util.BitSet getAvailableProcessors()
```

⁴⁰Section 6.4.2.1.1

⁴¹Section 6.4.2.1

⁴²Section 6.4.2.1.1

⁴³Section 6.4.2.1.1

This method is equivalent to `getAvailableProcessors(BitSet)`⁴⁴ with a `null` argument.

Returns

the set of processors available to the program.

getAvailableProcessors(BitSet)

Signature

```
public static final  
java.util.BitSet getAvailableProcessors(BitSet dest)
```

In systems where the set of processors available to a process is dynamic (e.g., because of system management operations or because of fault tolerance capabilities), the set of available processors shall reflect the processors that are allocated to the RTSJ runtime and are currently available to execute tasks.

Parameters

dest When **dest** is non-null, use **dest** as the returned value. When it is `null`, create a new `BitSet`.

Returns

A `BitSet` representing the set of processors currently valid for use in the `bitset` argument to `generate(BitSet)`⁴⁵.

get(RealtimeExecutionContext)

Signature

```
public static final  
javafx.runtime.Affinity get(RealtimeExecutionContext task)
```

Return the affinity set instance associated with `task`.

Parameters

task is the execution context to query.

Returns

The associated affinity.

set(Affinity, RealtimeExecutionContext)

Signature

⁴⁴Section 6.4.2.1.1

⁴⁵Section 6.4.2.1.1

```
public static final
void set(Affinity set,
        RealtimeExecutionContext task)
throws ProcessorAffinityException
```

Set the processor affinity of a `task`.

Parameters

`set` is the processor affinity

`task` is the execution context whose affinity will be set.

Throws

`ProcessorAffinityException` is thrown when the runtime fails to set the affinity for platform-specific reasons.

`NullPointerException` when `set` or `task` is null.

get(Thread)

Signature

```
public static final
javax.realtime.Affinity get(Thread thread)
```

Return the affinity set instance associated with `thread`.

Parameters

`thread` a Java thread, or one of its subclasses (including `RealtimeThread`⁴⁶).

Returns

The associated affinity set.

set(Affinity, Thread)

Signature

```
public static final
void set(Affinity set,
        Thread thread)
throws ProcessorAffinityException
```

Set the processor affinity of a Java thread or `RealtimeThread`⁴⁷ to `set`.

Parameters

`set` The processor affinity set

⁴⁶Section 5.3.2.2

⁴⁷Section 5.3.2.2

thread The thread or real-time thread.

Throws

ProcessorAffinityException when the runtime fails to set the affinity for platform-specific reasons.

NullPointerException when **set** or **thread** is null.

get(ThreadGroup)

Signature

```
public static final  
javax.realtime.Affinity get(ThreadGroup group)
```

Return the affinity set instance associated with **group**.

Parameters

group An instance of `java.lang.ThreadGroup`

Returns

The associated affinity set.

set(Affinity, ThreadGroup)

Signature

```
public static final  
void set(Affinity set,  
         ThreadGroup group)  
throws ProcessorAffinityException
```

Set the processor affinity of **group** to **set**.

Parameters

set The processor affinity set

group The processing group parameters instance.

Throws

ProcessorAffinityException when the runtime fails to set the affinity for platform-specific reasons or **group** contains more than one processor.

NullPointerException when **set** or **group** is null.

getProcessors

Signature


```
public final  
java.util.BitSet getProcessors()
```

Return a `BitSet` representing the processor affinity set for this `Affinity`.

Returns

A newly created `BitSet` representing this `Affinity`.

getProcessors(BitSet)

Signature

```
public final  
java.util.BitSet getProcessors(BitSet dest)
```

Return a `BitSet` representing the processor affinity set of this `Affinity`.

Parameters

`dest` Set `dest` to the `BitSet` value. When `dest` is null, create a new `BitSet` in the current allocation context.

Returns

A `BitSet` representing the processor affinity set of this `Affinity`.

isProcessorInSet(int)

Signature

```
public final  
boolean isProcessorInSet(int processorId)
```

Ask whether a processor is included in this affinity set.

Parameters

`processorId` a number identifying a single CPU in a multiprocessor system.

Returns

`true` when and only when `processorNumber` is represented in this affinity set.

applyTo(BoundAsyncEventHandler)

Signature

```
public final  
void applyTo(BoundAsyncEventHandler aeh)  
throws ProcessorAffinityException
```

Set the processor affinity of a bound AEH to **this**.

Parameters

aeh The bound async event handler

Throws

ProcessorAffinityException Thrown when the runtime fails to set the affinity for platform-specific reasons.

NullPointerException when **aeh** is **null**.

applyTo(Thread)

Signature

```
public final
void applyTo(Thread thread)
throws ProcessorAffinityException
```

Set the processor affinity of a Java thread or **RealtimeThread**⁴⁸ to **this**.

Parameters

thread The thread or realtime thread.

Throws

ProcessorAffinityException when the runtime fails to set the affinity for platform-specific reasons.

NullPointerException when **thread** is **null**.

applyTo(ProcessingGroup)

Signature

```
public final
void applyTo(ProcessingGroup group)
throws ProcessorAffinityException
```

Set the processor affinity of **group** to **this**.

Parameters

group The processing group parameters instance.

Throws

ProcessorAffinityException when the runtime fails to set the affinity for platform-specific reasons or **group** contains more than one processor.

NullPointerException when **group** is **null**.

⁴⁸Section [5.3.2.2](#)

applyTo(ActiveEventDispatcher)

Signature

```
public final  
void applyTo(javax.realtime.ActiveEventDispatcher<?, ?> dispatcher)  
throws ProcessorAffinityException
```

Set the processor affinity of `dispatcher` to this.

Parameters

`dispatcher` is the dispatcher instance.

Throws

`ProcessorAffinityException` when the runtime fails to set the affinity for platform-specific reasons.

`NullPointerException` when `dispatcher` is null.

6.4.2.2 AperiodicParameters

Inheritance

```
java.lang.Object  
  javax.realtime.ReleaseParameters  
    javax.realtime.AperiodicParameters
```

When a reference to an `AperiodicParameters` object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's setter methods, the `AperiodicParameters` object becomes the release parameters object bound to that schedulable. Changes to the values in the `AperiodicParameters` object affect that schedulable. When bound to more than one schedulable, changes to the values in the `AperiodicParameters` object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

Only changes to an `AperiodicParameters` object caused by methods on that object cause the change to propagate to all schedulables using the object. For instance, calling `setCost` on an `AperiodicParameters` object will make the change, then notify that the scheduler that the parameter object has changed. At that point the object is reconsidered for every schedulable that uses it. Invoking a method on the `RelativeTime` object that is the cost for this object may change the cost but it does not pass the change to the scheduler at that time. That change must not change the behavior of the schedulable's that use the parameter object until a setter method on the `AperiodicParameters` object is invoked, or the parameter object is used in `setReleaseParameters()` or a constructor for a schedulable.

Table 6.3: AperiodicParameters Default Values

Attribute	Value
cost	<code>new RelativeTime(0,0)</code>
deadline	<code>new RelativeTime(Long.MAX_VALUE, 999999)</code>
overrunHandler	None
missHandler	None
rousable	false
Arrival time queue size	0
Queue overflow policy	SAVE

The implementation must use modified copy semantics for each [HighResolutionTime](#)⁴⁹ parameter value. The value of each time object should be treated as if it were copied at the time it is passed to the parameter object, but the object reference must also be retained. For instance, the value returned by `getCost()` must be the same object passed in by `setCost()`, but any changes made to the time value of the cost must not take effect in the associated `AperiodicParameters` instance unless they are passed to the parameter object again, e.g. with a new invocation of `setCost`.

Correct initiation of the deadline miss and cost overrun handlers requires that the underlying system know the arrival time of each aperiodic task. For an instance of [RealtimeThread](#)⁵⁰ the arrival time is the time at which the `start()` is invoked. For other instances of [Schedulable](#)⁵¹, the required behaviors may require the implementation to behave effectively as if it maintained a queue of arrival times.

When the release parameters for a `RealtimeThread` are set to an instance of this class or one of its subclasses, the thread does not start executing code until the [RealtimeThread.release\(\)](#)⁵² method is called.

The following tables gives the default values for the constructors parameters.

6.4.2.2.1 Fields

arrivalTimeQueueOverflowExcept

⁴⁹Section [9.4.1.2](#)

⁵⁰Section [5.3.2.2](#)

⁵¹Section [6.4.1.3](#)

⁵²Section [5.3.2.2.2](#)

`public static final arrivalTimeQueueOverflowExcept`

Represents the “EXCEPT” policy for dealing with arrival time queue overflow. Under this policy, when an arrival occurs and its time should be queued but the queue already holds a number of times equal to the initial queue length defined by `this` then the `fire()` method shall throw a `ArrivalTimeQueueOverflowException`⁵³. Any other associated semantics are governed by the schedulers for the schedulables using these aperiodic parameters. When the arrival is a result of a happening to which the instance of `AsyncEventHandler`⁵⁴ is bound then the arrival time is ignored.

`arrivalTimeQueueOverflowIgnore`

`public static final arrivalTimeQueueOverflowIgnore`

Represents the “IGNORE” policy for dealing with arrival time queue overflow. Under this policy, when an arrival occurs and its time should be queued, but the queue already holds a number of times equal to the initial queue length defined by `this` then the arrival is ignored. Any other associated semantics are governed by the schedulers for the schedulables using these aperiodic parameters.

`arrivalTimeQueueOverflowReplace`

`public static final arrivalTimeQueueOverflowReplace`

Represents the “REPLACE” policy for dealing with arrival time queue overflow. Under this policy, when an arrival occurs and should be queued but the queue already holds a number of times equal to the initial queue length defined by `this` then the information for this arrival replaces a previous arrival. Any other associated semantics are governed by the schedulers for the schedulables using these aperiodic parameters.

`arrivalTimeQueueOverflowSave`

`public static final arrivalTimeQueueOverflowSave`

Represents the “SAVE” policy for dealing with arrival time queue overflow. Under this policy, when an arrival occurs and should be queued but the queue is full, then the queue is lengthened and the arrival time is saved. Any other associated semantics are governed by the schedulers for the schedulables using these aperiodic parameters. This policy does not update the “initial queue length” as it alters the

⁵³Section 14.3.2.1

⁵⁴Section 8.4.3.5

actual queue length. Since the **SAVE** policy grows the arrival time queue as necessary, for the **SAVE** policy the initial queue length is only an optimization.

6.4.2.2.2 Constructors

AperiodicParameters

Signature

```
public  
AperiodicParameters()
```

Create an `AperiodicParameters` object. This constructor is equivalent to

```
AperiodicParameters(null, null, null, null, false)
```

AperiodicParameters(RelativeTime)

Signature

```
public  
AperiodicParameters(RelativeTime deadline)
```

Create an `AperiodicParameters` object. This constructor is equivalent to

```
AperiodicParameters(null, deadline, null, null, false)
```

Parameters

`deadline` is the time after start of a release by which the release action should be completed.

AperiodicParameters(RelativeTime, AsyncEventHandler, boolean)

Signature

```
public  
AperiodicParameters(RelativeTime deadline,
```

```
AsyncEventHandler missHandler,  
boolean rousable)
```

Create an `AperiodicParameters` object. This constructor is equivalent to:

```
AperiodicParameters(null, deadline, null, missHandler, rousable)
```

Parameters

`deadline` is the time after start of a release by which the release action should be completed.

`missHandler` is a handler to call when the deadline is missed.

`roustable` determines whether or not an interrupt with cause an early release.

AperiodicParameters(RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
public  
AperiodicParameters(RelativeTime cost,  
                    RelativeTime deadline,  
                    AsyncEventHandler overrunHandler,  
                    AsyncEventHandler missHandler)
```

Create an `AperiodicParameters` object.

Parameters

`cost` Processing time per invocation. On implementations which can measure the amount of time a schedulable object is executed, this value is the maximum amount of time a schedulable receives. On implementations which cannot measure execution time, it is not possible to determine when any particular object exceeds `cost`. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

`deadline` The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When `null`, the default value is a new instance of `RelativeTime(Long.MAX_VALUE, 999999)`.

`overrunHandler` This handler is invoked when an invocation of the schedulable exceeds `cost`. Not required for minimum implementation. When `null`, the default value is no overrun handler.

`missHandler` This handler is invoked when the `run()` method of the schedulable object is still executing after the deadline has passed. When `null`, the

default value is no miss handler.

Throws

IllegalArgumentException when the time value of **cost** is less than zero, or the time value of **deadline** is less than or equal to zero.

IllegalAssignmentError when **cost**, **deadline**, **overrunHandler** or **missHandler** cannot be stored in this.

AperiodicParameters(RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler, boolean)

Signature

```
public
AperiodicParameters(RelativeTime cost,
                    RelativeTime deadline,
                    AsyncEventHandler overrunHandler,
                    AsyncEventHandler missHandler,
                    boolean rousable)
```

Create an **AperiodicParameters** object.

Parameters

cost Processing time per invocation. On implementations which can measure the amount of time a schedulable object is executed, this value is the maximum amount of time a schedulable receives. On implementations which cannot measure execution time, it is not possible to determine when any particular object exceeds **cost**. When **null**, the default value is a new instance of **RelativeTime(0,0)**.

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When **null**, the default value is a new instance of **RelativeTime(Long.MAX_VALUE, 999999)**.

overrunHandler This handler is invoked when an invocation of the schedulable exceeds **cost**. Not required for minimum implementation. When **null**, the default value is no overrun handler.

missHandler This handler is invoked when the **run()** method of the schedulable object is still executing after the deadline has passed. When **null**, the default value is no miss handler.

rousable determines whether or not an instance of **Schedulable** can be prematurely released by a thread interrupt.

Throws

`IllegalArgumentException` when the time value of `cost` is less than zero, or the time value of `deadline` is less than or equal to zero.

`IllegalAssignmentError` when `cost`, `deadline`, `overrunHandler` or `missHandler` cannot be stored in this.

6.4.2.2.3 Methods

getArrivalTimeQueueOverflowBehavior

Signature

```
public  
java.lang.String getArrivalTimeQueueOverflowBehavior()
```

Gets the behavior of the arrival time queue in the event of an overflow.

Returns

The behavior of the arrival time queue as a string.

getInitialArrivalTimeQueueLength

Signature

```
public  
int getInitialArrivalTimeQueueLength()
```

Gets the initial number of elements the arrival time queue can hold. This returns the initial queue length currently associated with this parameter object. When the overflow policy is **SAVE** the initial queue length may not be related to the current queue lengths of schedulables associated with this parameter object.

Returns

The initial length of the queue.

setDeadline(RelativeTime)

Signature

```
public  
void setDeadline(RelativeTime deadline)
```

Sets the deadline value.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as `Real-timeThread.setReleaseParameters(ReleaseParameters)`⁵⁵) the deadline of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When **deadline** is `null`, the deadline is set to a new instance of `RelativeTime(Long.MAX_VALUE, 999999)`.

Throws

`IllegalArgumentException` when the time value of **deadline** is less than or equal to zero, or when the new value of this deadline is incompatible with the scheduler for any associated schedulable.

`IllegalAssignmentError`

setArrivalTimeQueueOverflowBehavior(String)

Signature

```
public  
void setArrivalTimeQueueOverflowBehavior(String behavior)
```

Sets the behavior of the arrival time queue in the case where the insertion of a new element would make the queue size greater than the initial size given in this.

Values of **behavior** are compared using reference equality (`==`) not value equality (`equals()`).

Parameters

behavior A string representing the behavior.

Throws

`IllegalArgumentException` when **behavior** is not one of the final queue overflow behavior values defined in this class.

setInitialArrivalTimeQueueLength(int)

Signature

```
public  
void setInitialArrivalTimeQueueLength(int initial)
```

⁵⁵Section 5.3.2.2.2

Table 6.4: FirstInFirstOut Default PriorityParameter Values

Attribute	Default Value
Priority	norm priority

Sets the initial number of elements the arrival time queue can hold without lengthening the queue. The initial length of an arrival queue is set when the schedulable using the queue is constructed, after that time changes in the initial queue length are ignored.

Parameters

initial The initial length of the queue.

Throws

IllegalArgumentException when **initial** is less than zero.

6.4.2.3 FirstInFirstOutScheduler

Inheritance

```
java.lang.Object
  javax.realtime.Scheduler
    javax.realtime.PriorityScheduler
      javax.realtime.FirstInFirstOutScheduler
```

A version of **PriorityScheduler**⁵⁶ where once a thread is scheduled at a given priority, it runs until it is blocked or is preempted by a higher priority thread. When preempted, it remains the next thread ready for its priority. This is the default scheduler for realtime tasks. It represents the required (by the RTSJ) priority-based scheduler. The default instance is the base scheduler which does fixed priority, preemptive scheduling.

This scheduler, like all schedulers, governs the default values for scheduling-related parameters in its client schedulables. The defaults are as follows:

The system contains one instance of the **FirstInFirstOutScheduler** which is the system's base scheduler and is returned by **FirstInFirstOutScheduler.instance()**. The instance returned by the **instance()**⁵⁷ method is the *base scheduler* and is returned by **Scheduler.getDefaultScheduler()**⁵⁸ unless the default scheduler is reset with **Scheduler.setDefaultScheduler(Scheduler)**⁵⁹.

⁵⁶Section 6.4.2.7

⁵⁷Section 6.4.2.3.1

⁵⁸Section 6.4.2.11.2

⁵⁹Section 6.4.2.11.2

6.4.2.3.1 Methods

instance

Signature

```
public static  
    javax.realtime.PriorityScheduler instance()
```

Return a reference to the distinguished instance of `PriorityScheduler` which is the system's base scheduler.

Returns

A reference to the distinguished instance `PriorityScheduler`.

getMaxPriority

Signature

```
public  
    int getMaxPriority()
```

Gets the maximum priority available for a schedulable managed by this scheduler.

Returns

The value of the maximum priority.

getMinPriority

Signature

```
public  
    int getMinPriority()
```

Gets the minimum priority available for a schedulable managed by this scheduler.

Returns

The minimum priority used by this scheduler.

getNormPriority

Signature

```
public  
int getNormPriority()
```

Gets the normal priority available for a schedulable managed by this scheduler.

Returns

The value of the normal priority.

getPolicyName

Signature

```
public  
java.lang.String getPolicyName()
```

Gets the policy name of this.

Returns

The policy name (Fixed Priority First In First Out) as a string.

reschedule(Thread, int)

Signature

```
public  
void reschedule(Thread thread,  
                 int priority)
```

Promotes a `java.lang.Thread` to realtime priority under this scheduler. The affected thread will be scheduled as if it were a `RealtimeThread`⁶⁰ of the given priority. This does not make the affected thread a `RealtimeThread`, however, and it will not have access to facilities reserved for instances of `RealtimeThread`.

Parameters

thread The thread to promote to realtime scheduling.

priority An integer priority equivalent to a priority set via `PriorityParameters`⁶¹ on a `RealtimeThread`.

Throws

`IllegalArgumentException` when `priority` is not between `getMinPriority()`⁶² and `getMaxPriority()`⁶³, inclusive.

⁶⁰Section 5.3.2.2

⁶¹Section 6.4.2.6

⁶²Section 6.4.2.3.1

⁶³Section 6.4.2.3.1

6.4.2.4 ImportanceParameters

Inheritance

```
java.lang.Object
  javax.realtime.SchedulingParameters
    javax.realtime.PriorityParameters
      javax.realtime.ImportanceParameters
```

Importance is an additional scheduling metric that may be used by some priority-based scheduling algorithms during overload conditions to differentiate execution order among threads of the same priority.

In some realtime systems an external physical process determines the period of many threads. When rate-monotonic priority assignment is used to assign priorities, many of the threads in the system may have the same priority because their periods are the same. However, it is conceivable that some threads may be more important than others and in an overload situation importance can help the scheduler decide which threads to execute first. The base scheduling algorithm represented by [PriorityScheduler](#)⁶⁴ must not consider importance.

6.4.2.4.1 Constructors

ImportanceParameters(int, int)

Signature

```
public
ImportanceParameters(int priority,
                     int importance)
```

Create an instance of `ImportanceParameters`.

Parameters

priority The priority value assigned to schedulables that use this parameter instance. This value is used in place of the value passed to `Thread.setPriority`.

importance The importance value assigned to schedulable objects that use this parameter instance.

⁶⁴Section [6.4.2.7](#)

6.4.2.4.2 Methods

getImportance

Signature

```
public  
int getImportance()
```

Gets the importance value.

Returns

The value of importance for the associated instances of [Schedulable](#)⁶⁵.

setImportance(int)

Signature

```
public  
void setImportance(int importance)
```

Set the importance value. When this parameter object is associated with any schedulable (by being passed through the schedulable's constructor or set with a method such as [RealtimeThread.setSchedulingParameters\(SchedulingParameters\)](#)⁶⁶) the importance of those schedulables is altered at a moment controlled by the schedulers for the respective schedulables.

Parameters

importance The value to which importance is set.

Throws

[IllegalArgumentException](#) when the given importance value is incompatible with the scheduler for any of the schedulables which are presently using this parameter object.

toString

Signature

```
public  
java.lang.String toString()
```

⁶⁵Section [6.4.1.3](#)

⁶⁶Section [5.3.2.2.2](#)

Print the value of the priority and importance values of the associated instance of `Schedulable`⁶⁷

6.4.2.5 PeriodicParameters

Inheritance

```
java.lang.Object
  javax.realtime.ReleaseParameters
    javax.realtime.PeriodicParameters
```

This release parameter indicates that the schedulable is released on a regular basis. For an `AsyncEventHandler`⁶⁸, this means that the handler is either released by a periodic timer, or the associated event occurs periodically. For a `RealtimeThread`⁶⁹, this means that the `RealtimeThread.waitForNextRelease`⁷⁰ method will unblock the associated realtime thread at the start of each period.

When a reference to a `PeriodicParameters` object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's setter methods, the `PeriodicParameters` object becomes the release parameters object bound to that schedulable. Changes to the values in the `PeriodicParameters` object affect that schedulable object. When bound to more than one schedulable then changes to the values in the `PeriodicParameters` object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

Only changes to a `PeriodicParameters` object caused by methods on that object cause the change to propagate to all schedulable objects using the object. For instance, calling `setCost` on an `PeriodicParameters` object will make the change, then notify that the scheduler that the parameter object has changed. At that point the object is reconsidered for every SO that uses it. Invoking a method on the `RelativeTime` object that is the cost for this object may change the cost but it does not pass the change to the scheduler at that time. That change must not change the behavior of the SOs that use the parameter object until a setter method on the `PeriodicParameters` object is invoked, or the parameter object is used in `setReleaseParameters()` or a constructor for an SO.

⁶⁷Section 6.4.1.3

⁶⁸Section 8.4.3.5

⁶⁹Section 5.3.2.2

⁷⁰Section 5.3.2.2.2

Table 6.5: PeriodicParameter Default Values

Attribute	Default Value
start	new RelativeTime(0,0)
period	No default. A value must be supplied
cost	new RelativeTime(0,0)
deadline	new RelativeTime(period)
overrunHandler	None
missHandler	None

Periodic parameters use [HighResolutionTime](#)⁷¹ values for period and start time. Since these times are expressed as a [HighResolutionTime](#)⁷² values, these values use accurate timers with nanosecond granularity. The actual resolution available and even the quantity the timers measure depend on the clock associated with each time value.

The implementation must use modified copy semantics for each [HighResolutionTime](#)⁷³ parameter value. The value of each time object should be treated as if it were copied at the time it is passed to the parameter object, but the object reference must also be retained. For instance, the value returned by `getCost()` must be the same object passed in by `setCost()`, but any changes made to the time value of the cost must not take effect in the associated `PeriodicParameters` instance unless they are passed to the parameter object again, e.g. with a new invocation of `setCost`.

The following table gives the default parameter values for the constructors.

Periodic release parameters are strictly informational when they are applied to async event handlers. They must be used for any feasibility analysis, but release of the async event handler is not entirely controlled by the scheduler.

6.4.2.5.1 Constructors

PeriodicParameters(RelativeTime)

⁷¹Section [9.4.1.2](#)

⁷²Section [9.4.1.2](#)

⁷³Section [9.4.1.2](#)

Signature

```
public  
PeriodicParameters(RelativeTime period)
```

Create a `PeriodicParameters` object with the specified period and all other attributes set to their default values. This constructor has the same effect as invoking `PeriodicParameters(null, period, null, null, null, null, false)`

PeriodicParameters(HighResolutionTime, RelativeTime)*Signature*

```
public  
PeriodicParameters(javax.realtime.HighResolutionTime<?> start,  
                    RelativeTime period)
```

Create a `PeriodicParameters` object with the specified period and start times, and all other attributes set to their default values. This constructor has the same effect as invoking `PeriodicParameters(start, period, null, null, null, null, false)`

PeriodicParameters(HighResolutionTime, RelativeTime, RelativeTime, boolean)*Signature*

```
public  
PeriodicParameters(javax.realtime.HighResolutionTime<?> start,  
                    RelativeTime period,  
                    RelativeTime deadline,  
                    boolean rousable)
```

Create a `PeriodicParameters` object with the specified deadline, period and start times, and all other attributes set to their default values. This constructor has the same effect as invoking `PeriodicParameters(start, period, null, deadline, null, null, null, rousable)`

PeriodicParameters(HighResolutionTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
public
PeriodicParameters(javax.realtime.HighResolutionTime<?> start,
                    RelativeTime period,
                    RelativeTime cost,
                    RelativeTime deadline,
                    AsyncEventHandler overrunHandler,
                    AsyncEventHandler missHandler)
```

Create a `PeriodicParameters` object with attributes set to the specified values.

Parameters

start Time at which the first release begins (i.e. the real-time thread becomes eligible for execution.) When a `RelativeTime`, this time is relative to the first time the thread becomes activated (that is, when `start()` is called). When an `AbsoluteTime`, then the first release is the maximum of the start parameter and the time of the call to the associated `RealtimeThread.start()` method (modified according to any phasing policy). When null, the default value is a new instance of `RelativeTime(0,0)`.

period The period is the interval between successive unblocks of the `RealtimeThread.waitForNextRelease`⁷⁴ method. There is no default value. When `period` is null an exception is thrown.

cost Processing time per release. On implementations which can measure the amount of time a schedulable is executed, this value is the maximum amount of time a schedulable receives per release. When null, the default value is a new instance of `RelativeTime(0,0)`.

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When null, the default value is new instance of `RelativeTime(period)`.

overrunHandler This handler is invoked when an invocation of the schedulable exceeds cost in the given release. Implementations may ignore this parameter. When null, the default value is no overrun handler.

missHandler This handler is invoked when the `run()` method of the schedulable is still executing after the deadline has passed. When null, the default value is no deadline miss handler.

Throws

`IllegalArgumentException` when the `period` is null or its time value is not

⁷⁴Section 5.3.2.2.2

greater than zero, or when the time value of `cost` is less than zero, or when the time value of `deadline` is not greater than zero, or when the clock associated with the `cost` is not the realtime clock, or when the clock associated with the `start`, `deadline` and `period` parameters are not the same.

`IllegalAssignmentError` when `start` period, `cost`, `deadline`, `overrunHandler` or `missHandler` cannot be stored in this.

PeriodicParameters(HighResolutionTime, RelativeTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler, boolean)

Signature

```
public
PeriodicParameters(javafx.realtime.HighResolutionTime<?> start,
                    RelativeTime period,
                    RelativeTime cost,
                    RelativeTime deadline,
                    AsyncEventHandler overrunHandler,
                    AsyncEventHandler missHandler,
                    boolean rousable)
```

Create a `PeriodicParameters` object with attributes set to the specified values.

Parameters

start Time at which the first release begins (i.e. the real-time thread becomes eligible for execution.) When a `RelativeTime`, this time is relative to the first time the thread becomes activated (that is, when `start()` is called). When an `AbsoluteTime`, then the first release is the maximum of the start parameter and the time of the call to the associated `RealtimeThread.start()` method (modified according to any phasing policy). When null, the default value is a new instance of `RelativeTime(0,0)`.

period The period is the interval between successive unblocks of the `RealtimeThread.waitForNextRelease`⁷⁵ method. There is no default value. When `period` is null an exception is thrown.

cost Processing time per release. On implementations which can measure the amount of time a schedulable is executed, this value is the maximum amount of time a schedulable receives per release. When null, the default value is a new instance of `RelativeTime(0,0)`.

⁷⁵Section 5.3.2.2.2

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When null, the default value is new instance of `RelativeTime(period)`.

overflowHandler This handler is invoked when an invocation of the schedulable exceeds cost in the given release. Implementations may ignore this parameter. When null, the default value is no overflow handler.

missHandler This handler is invoked when the `run()` method of the schedulable is still executing after the deadline has passed. When null, the default value is no deadline miss handler.

rousable when `true`, and interrupt will cause an early release, otherwise not.

Throws

`IllegalArgumentException` when the `period` is null or its time value is not greater than zero, or when the time value of `cost` is less than zero, or when the time value of `deadline` is not greater than zero, or when the clock associated with the `cost` is not the realtime clock, or when the clock associated with the `start`, `deadline` and `period` parameters are not the same.

`IllegalAssignmentError` when `start` period, `cost`, `deadline`, `overflowHandler` or `missHandler` cannot be stored in `this`.

6.4.2.5.2 Methods

getPeriod

Signature

```
public  
javax.realtime.RelativeTime getPeriod()
```

Gets the period.

Returns

The current value in `period`.

getStart

Signature

```
public  
javax.realtime.HighResolutionTime<?> getStart()
```

Gets the start time.

Returns

The current value in `start`. This is the value that was specified in the constructor or by `setStart()`, not the actual absolute time corresponding to the start of one of the schedulable objects associated with this `PeriodicParameters` object.

setDeadline(RelativeTime)

Signature

```
public  
void setDeadline(RelativeTime deadline)
```

Sets the deadline value.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as `Real-timeThread.setReleaseParameters(ReleaseParameters)`⁷⁶) the deadline of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When **deadline** is `null`, the deadline is set to a new instance of `RelativeTime` equal to **period**.

Throws

`IllegalArgumentException` when the time value of **deadline** is less than or equal to zero, or when the new value of this deadline is incompatible with the scheduler for any associated schedulable.

`IllegalAssignmentError`

setPeriod(RelativeTime)

Signature

```
public  
void setPeriod(RelativeTime period)
```

Sets the period.

Parameters

period The value to which **period** is set.

Throws

⁷⁶Section 5.3.2.2.2

`IllegalArgumentException` when the given period is `null` or its time value is not greater than zero. Also when `period` is incompatible with the scheduler for any associated schedulable or when an associated `AsyncBaseEventHandler`⁷⁷ is associated with a `Timer`⁷⁸ whose period does not match `period`.

`IllegalAssignmentError` when `period` cannot be stored in `this`.

setStart(HighResolutionTime)

Signature

```
public
void setStart(javax.realtime.HighResolutionTime<?> start)
```

Sets the start time.

The effect of changing the start time for any schedulables associated with this parameter object is determined by the scheduler associated with each schedulable.

Note: An instance of `PeriodicParameters` may be shared by several schedulables. A change to the start time may take effect on a subset of these schedulables. That leaves the start time returned by `getStart` unreliable as a way to determine the start time of a schedulable.

Parameters

`start` The new start time. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

Throws

`IllegalArgumentException` when the given start time is incompatible with the scheduler for any of the schedulable objects which are presently using this parameter object.

`IllegalAssignmentError` when `start` cannot be stored in `this`.

6.4.2.6 PriorityParameters

Inheritance

```
java.lang.Object
  javax.realtime.SchedulingParameters
    javax.realtime.PriorityParameters
```

Instances of this class should be assigned to schedulables that are managed by schedulers which use a single integer to determine execution order. The base scheduler

⁷⁷Section 8.4.3.3

⁷⁸Section 10.4.2.5

required by this specification and represented by the class `PriorityScheduler`⁷⁹ is such a scheduler.

6.4.2.6.1 Constructors

PriorityParameters(int)

Signature

```
public
PriorityParameters(int priority)
```

Create an instance of `PriorityParameters`⁸⁰ with the given priority.

Parameters

priority The priority assigned to schedulables that use this parameter instance.

6.4.2.6.2 Methods

getPriority

Signature

```
public
int getPriority()
```

Gets the priority value.

Returns

The priority.

setPriority(int)

Signature

⁷⁹Section 6.4.2.7

⁸⁰Section 6.4.2.6


```
public  
void setPriority(int priority)
```

Set the priority value. When this parameter object is associated with any schedulable (by being passed through the schedulable's constructor or set with a method such as `RealtimeThread.setSchedulingParameters(SchedulingParameters)`⁸¹) the base priority of those schedulables is altered as specified by each schedulable's scheduler.

Parameters

priority The value to which priority is set.

Throws

`IllegalArgumentException` when the given priority value is incompatible with the scheduler for any of the schedulables which are presently using this parameter object.

toString

Signature

```
public  
java.lang.String toString()
```

Converts the priority value to a string.

Returns

A string representing the value of priority.

6.4.2.7 PriorityScheduler

Inheritance

```
java.lang.Object  
    javax.realtime.Scheduler  
        javax.realtime.PriorityScheduler
```

Class which represents the required (by the RTSJ) priority-based scheduler. The default instance is the base scheduler which uses a fixed priority, first-in-first-out, preemptive scheduling algorithm.

This scheduler, like all schedulers, governs the default values for scheduling-related parameters in its client schedulables. The defaults are as follows:

⁸¹Section 5.3.2.2.2

Table 6.6: PriorityScheduler Default PriorityParameter Values

Attribute	Default Value
Priority	norm priority

Note that the system contains one instance of the `PriorityScheduler` which is the system's base scheduler and is returned by `FirstInFirstOutScheduler.instance()`⁸². It may, however, contain instances of subclasses of `PriorityScheduler` created through this class' protected constructor. The instance returned by the `FirstInFirstOutScheduler.instance()` method, the *base scheduler*, is returned by `Scheduler.getDefaultScheduler()`⁸³ unless the default scheduler is changed with `Scheduler.setDefaultScheduler(Scheduler)`⁸⁴.

6.4.2.7.1 Fields

MAX_PRIORITY

```
public static final MAX_PRIORITY
```

The maximum priority value used by the implementation.

MIN_PRIORITY

```
public static final MIN_PRIORITY
```

The minimum priority value used by the implementation.

6.4.2.7.2 Constructors

PriorityScheduler

Signature

⁸²Section 6.4.2.3.1

⁸³Section 6.4.2.11.2

⁸⁴Section 6.4.2.11.2

```
protected  
PriorityScheduler()
```

Construct an instance of `PriorityScheduler`. Applications will likely not need any instance other than the default instance.

6.4.2.7.3 Methods

`getPolicyName`

Signature

```
public  
java.lang.String getPolicyName()
```

Gets the policy name of `this`.

Returns

The policy name (Fixed Priority) as a string.

`getMaxPriority`

Signature

```
public abstract  
int getMaxPriority()
```

Gets the maximum priority available for a schedulable managed by this scheduler.

Returns

The value of the maximum priority.

`getMinPriority`

Signature

```
public abstract  
int getMinPriority()
```

Gets the minimum priority available for a schedulable managed by this scheduler.

Returns

The minimum priority used by this scheduler.

getNormPriority

Signature

```
public abstract  
int getNormPriority()
```

Gets the normal priority available for a schedulable managed by this scheduler.

Returns

The value of the normal priority.

reschedule(Thread, int)

Signature

```
public abstract  
void reschedule(Thread thread,  
                 int priority)
```

Promotes a `java.lang.Thread` to realtime priority under this scheduler. The affected thread will be scheduled as if it were a `RealtimeThread`⁸⁵ of the given priority. This does not make the affected thread a `RealtimeThread`, however, and it will not have access to facilities reserved for instances of `RealtimeThread`.

Parameters

thread The thread to promote to realtime scheduling.

priority An integer priority equivalent to a priority set via `PriorityParameters`⁸⁶ on a `RealtimeThread`.

Throws

`IllegalArgumentException` when **priority** is not between `getMinPriority()`⁸⁷ and `getMaxPriority()`⁸⁸, inclusive.

6.4.2.8 ProcessingGroup

Inheritance

```
java.lang.Object  
  java.lang.ThreadGroup
```

⁸⁵Section 5.3.2.2

⁸⁶Section 6.4.2.6

⁸⁷Section 6.4.2.7.3

⁸⁸Section 6.4.2.7.3

`javafx.runtime.SchedulingGroup`
`javafx.runtime.ProcessingGroup`

A subclass of `ThreadGroup` for handling tasks, instances of `Schedulable`⁸⁹ and `java.lang.Thread`, as a single group. The cost of the group can be both traced and limited over a given period. The motivation for this class is to enable the execution demands of a group of tasks to be bound.

A processing group has an associated affinity. The precision of cost monitoring is dependent on the number of processes in the thread group. In the worst case, it is the base precision times the number of processes in the processing group. The default affinity is that which was inherited from the parent `SchedulingGroup`.

For all tasks with a reference to an instance of `ProcessingGroup` `p`, no more than `p.cost` will be allocated to the execution of these schedulables on the processors associated with its processing group in each interval of time given by `p.period` after the time indicated by `p.start`. No execution of the schedulables will be allowed on any processor other than these processors. There must be at least one processor in the intersection between the a schedulable object's affinity and its processing group's affinity.

Logically `ProcessingGroup` represents a virtual server. This server has a start time, a period, a cost (budget) and a deadline. The server can only logically execute when (a) it has not consumed more execution time in its current release than the cost (budget) parameter, (b) one of its associated schedulables is executable and is the most eligible of the executable schedulables. When the server is logically executable, the associated schedulables are executed. When the cost has been consumed, any `overrunHandler` is released, and the server is not eligible for logical execution until the period is finished. At this point, its allocated cost (budget) is replenished. When the server is logically executing when its deadline expires, any associated `missHandler` is released. The deadline and cost parameters of all the associated schedulable objects have the same impact as they would if the objects were not bound to a processing group.

Processing group parameters use `HighResolutionTime`⁹⁰ values for cost, deadline, period and start time. Since those times are expressed as a `HighResolutionTime`⁹¹, the values use accurate timers with nanosecond granularity. The actual resolution available and even the quantity it measures depends on the clock associated with each time value.

When a reference to a `ProcessingGroup` object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's setter methods, the `ProcessingGroup` object becomes the processing group parameters object bound to that schedulable object. Changes to the values in the `Process-`

⁸⁹Section 6.4.1.3

⁹⁰Section 9.4.1.2

⁹¹Section 9.4.1.2

Table 6.7: ProcessingGroup Default Values

Attribute	Default Value
start	new RelativeTime(0,0)
period	No default. A value must be supplied
cost	No default. A value must be supplied
deadline	new RelativeTime(period)
overrunHandler	None
missHandler	None

ingGroup object affect that schedulable object. When bound to more than one schedulable then changes to the values in the ProcessingGroup object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

The implementation must use modified copy semantics for each [HighResolutionTime](#)⁹² parameter value. The value of each time object should be treated as if it were copied at the time it is passed to the parameter object, but the object reference must also be retained. Only changes to a ProcessingGroup object caused by methods on that object are immediately visible to the scheduler. For instance, invoking `setPeriod()` on a ProcessingGroup object will make the change, then notify that the scheduler that the parameter object has changed. At that point the scheduler's view of the processing group parameters object is updated. Invoking a method on the RelativeTime object that is the period for this object may change the period but it does not pass the change to the scheduler at that time. That new value for period must not change the behavior of the SOs that use the parameter object until a setter method on the ProcessingGroup object is invoked or a constructor for an SO.

The implementation may use copy semantics for each HighResolutionTime parameter value. For instance the value returned by `getCost()` must be equal to the value passed in by `setCost`, but it need not be the same object.

The following table gives the default parameter values for the constructors.

Caution: This class is explicitly unsafe in multithreaded situations when it is being changed. No synchronization is done. It is assumed that users of this class who are mutating instances will be doing their own synchronization at a higher level.

Caution: The `cost` parameter time should be considered to be measured against the target platform.

⁹²Section [9.4.1.2](#)

6.4.2.8.1 Constructors

ProcessingGroup(String)

Signature

```
public  
ProcessingGroup(String name)
```

*Create**Parameters*

name

ProcessingGroup(SchedulingGroup, String)

Signature

```
public  
ProcessingGroup(SchedulingGroup parent,  
                String name)
```

6.4.2.8.2 Methods

getStart

Signature

```
public  
java.xml.realtime.HighResolutionTime<?> getStart()
```

Gets the value of **start**. This is the value that was specified in the constructor or by **setStart()**, not the absolute time corresponding to the actual start of the processing group.

Returns

A reference to an instance of `HighResolutionTime`⁹³ that represents the value of `start`.

setStart(HighResolutionTime)

Signature

```
public
void setStart(javax.realtime.HighResolutionTime<?> start)
throws IllegalArgumentException,
       IllegalAssignmentError
```

Sets the value of `start`. When the processing group is already started this method alters the value of this object's start time property, but has no other effect.

Parameters

`start` The new value for `start`. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

Throws

`IllegalAssignmentError` when `start` cannot be stored in `this`.
`IllegalArgumentException` when `start` is a relative time value and less than zero.

getPeriod

Signature

```
public
javax.realtime.RelativeTime getPeriod()
```

Gets the value of `period`.

Returns

A reference to an instance of `RelativeTime`⁹⁴ that represents the value of `period`.

setPeriod(RelativeTime)

Signature

```
public
void setPeriod(RelativeTime period)
```

⁹³Section [9.4.1.2](#)

⁹⁴Section [9.4.1.3](#)

throws `IllegalArgumentException`,
`IllegalAssignmentError`

Sets the value of `period`.

Parameters

`period` The new value for `period`. There is no default value. When `period` is null an exception is thrown.

Throws

`IllegalArgumentException` when `period` is null, or its time value is not greater than zero. When the implementation does not support processing group deadline less than period, and `period` is not equal to the current value of the processing group's deadline, the deadline is set to a clone of `period` created in the same memory area as `period`.

`IllegalAssignmentError` when `period` cannot be stored in `this`.

getCost

Signature

```
public  
javax.realtime.RelativeTime getCost()
```

Gets the value of `cost`.

Returns

a reference to the value of `cost`.

setCost(RelativeTime)

Signature

```
public  
void setCost(RelativeTime cost)  
throws IllegalArgumentException,  
    IllegalAssignmentError
```

Sets the value of `cost`.

Parameters

`cost` The new value for `cost`. When null, an exception is thrown.

Throws

`IllegalArgumentException` when `cost` is null or its time value is less than zero.

`IllegalAssignmentError` when `cost` cannot be stored in `this`.

setCostOverrunHandler(AsyncEventHandler)

Signature

```
public  
void setCostOverrunHandler(AsyncEventHandler handler)  
throws IllegalArgumentException
```

Sets the cost overrun handler.

Parameters

handler This handler is invoked when the `run()` method of and of the the schedulables attempt to execute for more than `cost` time units in any period. When `null`, no handler is attached, and any previous handler is removed.

Throws

`IllegalArgumentException` when `handler` cannot be stored in `this`.

getCostOverrunHandler

Signature

```
public  
javax.realtime.AsyncEventHandler getCostOverrunHandler()
```

Gets the cost overrun handler.

Returns

A reference to an instance of [AsyncEventHandler](#)⁹⁵ that is cost overrun handler of `this`.

getCurrentCost(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getCurrentCost(RelativeTime dest)
```

Get the cost used in the current period so far.

Parameters

dest is the instance to use for returning the time.

Returns

dest containing the cost of the current period

⁹⁵Section [8.4.3.5](#)

getLastCost(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getLastCost(RelativeTime dest)
```

Get the total cost used in the last period.

Parameters

dest is the instance to use for returning the time.

Returns

dest containing the cost of the last period

getGranularity

Signature

```
public  
long getGranularity()
```

Determine the granularity of cost monitoring and cost enforcement.

Returns

the granularity in nanoseconds.

setGranularity(long)

Signature

```
public  
void setGranularity(long nanos)  
throws IllegalArgumentException
```

Set the granularity of cost monitoring and cost enforcement. The system provides a lower bounds for this. When set below the lower bound, granularity is set to this lower bound. In general, this is the precision of the realtime clock.

Parameters

nanos the new granularity in nanoseconds.

Throws

IllegalArgumentException when **nanos** is less than one.

6.4.2.9 ReleaseParameters

Inheritance

java.lang.Object
 javafx.realtime.ReleaseParameters

Interfaces

Cloneable
Serializable

The top-level class for release characteristics of schedulable objects. When a reference to a `ReleaseParameters` object is given as a parameter to a constructor of a schedulable, the `ReleaseParameters` object becomes bound to the object being created. Changes to the values in the `ReleaseParameters` object affect the constructed object. When given to more than one constructor, then changes to the values in the `ReleaseParameters` object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many. Only changes to an `ReleaseParameters` object caused by methods on that object cause the change to propagate to all schedulables using the object. For instance, invoking `setDeadline` on a `ReleaseParameters` instance will make the change, and then notify that the scheduler that the object has been changed. At that point the object is reconsidered for every SO that uses it. Invoking a method on the `RelativeTime` object that is the deadline for this object may change the time value but it does not pass the new time value to the scheduler at that time. Even though the changed time value is referenced by `ReleaseParameters` objects, it will not change the behavior of the SOs that use the parameter until a setter method on the `ReleaseParameters` object is invoked, or the parameter object is used in `setReleaseParameters()` or a constructor for a schedulable.

Release parameters use `HighResolutionTime`⁹⁶ values for cost, and deadline. Since the times are expressed as a `HighResolutionTime`⁹⁷ values, these values use accurate timers with nanosecond granularity. The actual precision available and even the quantity the timers measure depend on the clock associated with each time value.

The implementation must use modified copy semantics for each `HighResolutionTime`⁹⁸ parameter value. The value of each time object should be treated as when it were copied at the time it is passed to the parameter object, but the object reference must also be retained. For instance, the value returned by `getCost()` must be the same object passed in by `setCost()`, but any changes made to the time

⁹⁶Section 9.4.1.2

⁹⁷Section 9.4.1.2

⁹⁸Section 9.4.1.2

Table 6.8: ReleaseParameter Default Values

Attribute	Default Value
cost	new RelativeTime(0,0)
deadline	no default
overrunHandler	None
missHandler	None

value of the cost must not take effect in the associated `ReleaseParameters` instance unless they are passed to the parameter object again, e.g. with a new invocation of `setCost`.

The following table gives the default parameter values for the constructors.

6.4.2.9.1 Constructors

ReleaseParameters

Signature

```
protected
ReleaseParameters()
```

Create a new instance of `ReleaseParameters`. This constructor creates a default `ReleaseParameters` object, i.e., it is equivalent to `ReleaseParameters(null, null, null, null)`.

ReleaseParameters(RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
protected
ReleaseParameters(RelativeTime cost,
                  RelativeTime deadline,
                  AsyncEventHandler overrunHandler,
                  AsyncEventHandler missHandler)
```

Create a new instance of **ReleaseParameters** with the given parameter values.

Parameters

cost - Processing time units per release. On implementations which can measure the amount of time a schedulable object is executed, When null, the default value is a new instance of `RelativeTime(0,0)`.

deadline - The latest permissible completion time measured from the release time of the associated invocation of the schedulable. There is no default for deadline in this class. The default must be determined by the subclasses.

overflowHandler - This handler is invoked when an invocation of the schedulable exceeds cost. In the minimum implementation overflowHandler is ignored. When null, no application event handler is executed on cost overrun.

missHandler - This handler is invoked when the `run()` method of the schedulable is still executing after the deadline has passed. When null, no application event handler is executed on the miss deadline condition.

Throws

`java.lang.IllegalArgumentException` - when the time value of cost is less than zero, or the time value of deadline is less than or equal to zero or the clock associated with the **cost** parameters is not the real-time clock.

`IllegalAssignmentError` - when cost, deadline, overflowHandler, or missHandler cannot be stored in this.

ReleaseParameters(RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler, boolean)

Signature

```
protected
ReleaseParameters(RelativeTime cost,
                  RelativeTime deadline,
                  AsyncEventHandler overflowHandler,
                  AsyncEventHandler missHandler,
                  boolean rousable)
```

Create a new instance of **ReleaseParameters** with the given parameter values.

Parameters

cost - Processing time units per release. On implementations which can measure the amount of time a schedulable object is executed, When null, the default value is a new instance of `RelativeTime(0,0)`.

deadline - The latest permissible completion time measured from the release

time of the associated invocation of the schedulable. There is no default for deadline in this class. The default must be determined by the subclasses.

overflowHandler - This handler is invoked when an invocation of the schedulable exceeds cost. In the minimum implementation overflowHandler is ignored. When null, no application event handler is executed on cost overrun.

missHandler - This handler is invoked when the run() method of the schedulable is still executing after the deadline has passed. When null, no application event handler is executed on the miss deadline condition.

rounable determines whether or not an instance of **Schedulable** can be prematurely released by a thread interrupt.

Throws

java.lang.IllegalArgumentException - when the time value of cost is less than zero, or the time value of deadline is less than or equal to zero or the clock associated with the **cost** parameters is not the real-time clock.

IllegalAssignmentError - when cost, deadline, overflowHandler, or missHandler cannot be stored in this.

6.4.2.9.2 Methods

clone

Signature

```
public  
java.lang.Object clone()
```

Return a clone of **this**. This method should behave effectively as when it constructed a new object with clones of the high-resolution time values of **this**.

- The new object is in the current allocation context.
- **clone** does not copy any associations from **this** and it does not implicitly bind the new object to a SO.
- The new object has clones of all high-resolution time values (deep copy).
- References to event handlers are copied (shallow copy.)

getCost

Signature

```
public  
javax.realtime.RelativeTime getCost()
```

Gets a reference to the cost.

Returns

A reference to cost.

getCostOverrunHandler

Signature

```
public  
javax.realtime.AsyncEventHandler getCostOverrunHandler()
```

Gets a reference to the cost overrun handler.

Returns

A reference to the associated cost overrun handler.

getDeadline

Signature

```
public  
javax.realtime.RelativeTime getDeadline()
```

Gets a reference to the deadline.

Returns

A reference to deadline.

getDeadlineMissHandler

Signature

```
public  
javax.realtime.AsyncEventHandler getDeadlineMissHandler()
```

Gets a reference to the deadline miss handler.

Returns

A reference to the deadline miss handler.

setCost(RelativeTime)

Signature

```
public  
void setCost(RelativeTime cost)
```

Sets the cost value.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as `Real-timeThread.setReleaseParameters(ReleaseParameters)`⁹⁹) the cost of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

cost Processing time units per release. On implementations which can measure the amount of time a schedulable is executed, this value is the maximum amount of time a schedulable receives per release. On implementations which cannot measure execution time, it is not possible to determine when any particular object exceeds cost. When **null**, the default value is a new instance of `RelativeTime(0,0)`.

Throws

`IllegalArgumentException` when the time value of **cost** is less than zero, or the clock associated with the **cost** parameters is not the real-time clock.

`IllegalAssignmentError` when **cost** cannot be stored in **this**.

setCostOverrunHandler(AsyncEventHandler)

Signature

```
public  
void setCostOverrunHandler(AsyncEventHandler handler)
```

Sets the cost overrun handler.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as `Real-timeThread.setReleaseParameters(ReleaseParameters)`¹⁰⁰) the cost overrun handler of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

⁹⁹Section 5.3.2.2.2

¹⁰⁰Section 5.3.2.2.2

handler This handler is invoked when an invocation of the schedulable attempts to exceed **cost** time units in a release. A **null** value of **handler** signifies that no cost overrun handler should be used.

Throws

IllegalAssignmentError when **handler** cannot be stored in **this**.

setDeadline(RelativeTime)

Signature

```
public  
void setDeadline(RelativeTime deadline)
```

Sets the deadline value.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as **Real-timeThread.setReleaseParameters(ReleaseParameters)**¹⁰¹) the deadline of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. The default value of the deadline must be controlled by the classes that extend **ReleaseParameters**.

Throws

IllegalArgumentException when **deadline** is **null**, the time value of **deadline** is less than or equal to zero, or when the new value of this deadline is incompatible with the scheduler for any associated schedulable.

IllegalAssignmentError when **deadline** cannot be stored in **this**.

setDeadlineMissHandler(AsyncEventHandler)

Signature

```
public  
void setDeadlineMissHandler(AsyncEventHandler handler)
```

Sets the deadline miss handler.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as **Real-timeThread.setReleaseParameters(ReleaseParameters)**¹⁰²) the deadline miss han-

¹⁰¹Section 5.3.2.2.2

¹⁰²Section 5.3.2.2.2

handler of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

handler This handler is invoked when any release of the schedulable fails to complete before the deadline passes. A **null** value of **handler** signifies that no deadline miss handler should be used.

Throws

IllegalAssignmentError when **handler** cannot be stored in **this**.

isRousable

Signature

```
public  
boolean isRousable()
```

Determine whether or not a thread interrupt will cause instances of **Schedulable** associated with an instance of this class will be prematurely released.

Returns

true when rousable and **false** when not.

setRousable(boolean)

Signature

```
public  
void setRousable(boolean value)
```

Dictate whether or not a thread interrupt will cause instances of **Schedulable** associated with an instance of this class will be prematurely released.

Parameters

value is **true** when rousable and **false** when not.

6.4.2.10 RoundRobinScheduler

Inheritance

```
java.lang.Object  
  javax.realtime.Scheduler  
    javax.realtime.PriorityScheduler  
      javax.realtime.RoundRobinScheduler
```

Class which represents a priority-based round-robin scheduler.

The default instance of this scheduler (returned by `instance()`¹⁰³) represents the RTSJ-specified round-robin scheduler.

6.4.2.10.1 Methods

instance

Signature

```
public static  
    javax.realtime.RoundRobinScheduler instance()
```

Return a reference to the distinguished instance of `RoundRobinScheduler` which is the RTSJ-specified round-robin scheduler.

Throws

`UnsupportedOperationException` if this platform has no default round-robin scheduler.

Returns

A reference to the distinguished instance of `RoundRobinScheduler`

setQuantum(RelativeTime)

Signature

```
public  
    void setQuantum(RelativeTime quantum)  
    throws UnsupportedOperationException,  
           IllegalArgumentException
```

Set the quantum of this instance of `RoundRobinScheduler`. This takes effect at the end of the current quantum.

Parameters

quantum The new quantum to use. Copy semantics are used for this argument, and future changes to **quantum** will not affect this scheduler unless it is again passed to `setQuantum()`.

Throws

¹⁰³Section 6.4.2.10.1

`UnsupportedOperationException` if this scheduler's quantum is not configurable at runtime.

`IllegalArgumentException` if the provided quantum is null, less than zero, or not appropriate for this platform.

getQuantum

Signature

```
public  
javax.realtime.RelativeTime getQuantum()
```

Get the quantum of this instance of `RoundRobinScheduler`.

Returns

a newly-allocated `RelativeTime` containing the currently-configured quantum of this scheduler.

getQuantum(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getQuantum(RelativeTime dest)
```

Get the quantum of this instance of `RoundRobinScheduler`.

Parameters

`dest` return the quantum in `dest` . When `dest` is null, allocate a new `RelativeTime`¹⁰⁴ instance to hold the returned value.

Returns

The currently-configured quantum of this scheduler.

getMaxPriority

Signature

```
public  
int getMaxPriority()
```

Gets the maximum priority available for a schedulable managed by this scheduler.

Returns

The value of the maximum priority.

¹⁰⁴Section 9.4.1.3

getMinPriority

Signature

```
public  
int getMinPriority()
```

Gets the minimum priority available for a schedulable managed by this scheduler.

Returns

The minimum priority used by this scheduler.

getNormPriority

Signature

```
public  
int getNormPriority()
```

Gets the normal priority available for a schedulable managed by this scheduler.

Returns

The value of the normal priority.

getPolicyName

Signature

```
public  
java.lang.String getPolicyName()
```

Gets the policy name of **this**.

Returns

The policy name (Fixed Priority Round Robin) as a string.

reschedule(Thread, int)

Signature

```
public  
void reschedule(Thread thread,  
                 int priority)
```

Promotes a `java.lang.Thread` to realtime priority under this scheduler. The affected thread will be scheduled as if it were a `RealtimeThread`¹⁰⁵ of the given priority. This does not make the affected thread a `RealtimeThread`, so it will not have access to facilities reserved for instances of `RealtimeThread`.

The method `Thread.setPriority(int)` can be used to reschedule back to the conventional Java priority levels.

Parameters

thread The thread to promote to realtime scheduling.

priority An integer priority equivalent to a priority set via `PriorityParameters`¹⁰⁶ on a `RealtimeThread`.

Throws

`IllegalArgumentException` when `thread` is null or `priority` is not between `getMinPriority()`¹⁰⁷ and `getMaxPriority()`¹⁰⁸, inclusive.

6.4.2.11 Scheduler

Inheritance

`java.lang.Object`
`javax.realtime.Scheduler`

An instance of `Scheduler` manages the execution of schedulables.

Subclasses of `Scheduler` are used for alternative scheduling policies and should define an `instance()` class method to return the default instance of the subclass. The name of the subclass should be descriptive of the policy, allowing applications to deduce the policy available for the scheduler obtained via `Scheduler.getDefaultScheduler`¹⁰⁹ (e.g., `EDFScheduler`).

6.4.2.11.1 Constructors

Scheduler

Signature

¹⁰⁵Section 5.3.2.2

¹⁰⁶Section 6.4.2.6

¹⁰⁷Section 6.4.2.10.1

¹⁰⁸Section 6.4.2.10.1

¹⁰⁹Section 6.4.2.11.2

```
protected  
Scheduler()
```

Create an instance of `Scheduler`.

6.4.2.11.2 Methods

`getDefaultScheduler`

Signature

```
public static  
javax.realtime.Scheduler getDefaultScheduler()
```

Gets a reference to the default scheduler.

Returns

A reference to the default scheduler.

`setDefaultScheduler(Scheduler)`

Signature

```
public static  
void setDefaultScheduler(Scheduler scheduler)
```

Sets the default scheduler. This is the scheduler given to instances of schedulables when they are constructed by a Java thread. The default scheduler is set to the required `PriorityScheduler`¹¹⁰ at startup.

Parameters

scheduler The `Scheduler` that becomes the default scheduler assigned to new schedulables created by Java threads. When `null` nothing happens.

Throws

`SecurityException` when the caller is not permitted to set the default scheduler.

`getPolicyName`

Signature

¹¹⁰Section 6.4.2.7


```
public abstract  
java.lang.String getPolicyName()
```

Gets a string representing the policy of **this**. The string value need not be interned, but it must be created in a memory area that does not cause an illegal assignment error when stored in the current allocation context and does not cause a [MemoryAccessError](#)¹¹¹ when accessed.

Returns

A **name** object which is the name of the scheduling policy used by **this**.

inSchedulableExecutionContext

Signature

```
public static  
boolean inSchedulableExecutionContext()
```

Determine whether the current calling context is a [Schedulable](#)¹¹²: [Realtime-Thread](#)¹¹³ or [AsyncBaseEventHandler](#)¹¹⁴.

Returns

true when yes and **false** otherwise.

currentSchedulable

Signature

```
public static  
javax.realtime.Schedulable currentSchedulable()
```

Get the current execution context when called from a [Schedulable](#)¹¹⁵ execution context.

Throws

[ClassCastException](#) when the caller is not a [Schedulable](#)¹¹⁶

Returns

the current [Schedulable](#)¹¹⁷.

¹¹¹Section [14.3.3.4](#)

¹¹²Section [6.4.1.3](#)

¹¹³Section [5.3.2.2](#)

¹¹⁴Section [8.4.3.3](#)

¹¹⁵Section [6.4.1.3](#)

¹¹⁶Section [6.4.1.3](#)

¹¹⁷Section [6.4.1.3](#)

6.4.2.12 SchedulingGroup

Inheritance

```
java.lang.Object
  java.lang.ThreadGroup
    javax.realtime.SchedulingGroup
```

6.4.2.12.1 Constructors

SchedulingGroup(String)

Signature

```
public
SchedulingGroup(String name)
throws IllegalStateException,
    IllegalAssignmentError
```

Create a new group with the current `ThreadGroup` instance as its parent, so long as it is an instance of `SchedulingGroup`.

Parameters

name is the name of the new group

Throws

`IllegalStateException` when the parent `ThreadGroup` instance is not an instance of `SchedulingGroup`.

`IllegalAssignmentError` when the parent `ThreadGroup` instance is not assignable to this.

SchedulingGroup(SchedulingGroup, String)

Signature

```
public
SchedulingGroup(SchedulingGroup parent,
                String name)
```

Create a new scheduling group.

Parameters

parent

name is the name of the new group

Throws

IllegalStateException when the parent **ThreadGroup** instance is not an instance of **SchedulingGroup**.

IllegalAssignmentError when the parent **ThreadGroup** instance is not assignable to this.

6.4.2.12.2 Methods

getMaxSchedulingParameters

Signature

```
public  
java.xml.realtime.SchedulingParameters getMaxSchedulingParameters()
```

Find the upper bound on scheduling eligibility that tasks in this group may have. For example, when it is an instance of **PriorityParameters**, it gives the maximum priority any thread in the group may have.

Returns

the scheduling parameter instance denoting the upper bound on the scheduling eligibility of threads in this group.

setMaxSchedulingParameters(SchedulingParameters)

Signature

```
public  
void setMaxSchedulingParameters(SchedulingParameters parameters)  
throws IllegalStateException
```

Set the upper bound on scheduling eligibility that tasks in this group may have. For example, when it is an instance of **PriorityParameters**, it sets the maximum priority any thread in the group may have.

Parameters

parameters the scheduling parameter instance denoting the new upper bound on the scheduling eligibility of threads in this group.

Throws

IllegalStateException when **parameters** are not consistent with the scheduler type.

getScheduler

Signature

```
public  
java.lang.Class<javax.realtime.Scheduler> getScheduler()
```

Find the type of scheduler tasks in this group may use. The scheduler of each thread must be an instance of the type returned. The default is **class<Scheduler>**, but it may be set to any subtype.

Returns

the scheduler type

setScheduler(Class)

Signature

```
public  
void setScheduler(java.lang.Class< javax.realtime.Scheduler> type)
```

Limit the schedulers that may be used for tasks in this group.

Parameters

type is the type of scheduler of which the schedulers of all tasks must be instances.

Throws

IllegalStateException when a thread in the group has a scheduler that is not an instance of **type** or **getMaxSchedulingParameters**¹¹⁸ returns parameters that are inconsistent with the scheduler type.

6.4.2.13 SchedulingParameters

Inheritance

java.lang.Object

¹¹⁸Section [6.4.2.12.2](#)

`javax.realtime.SchedulingParameters`

Interfaces

`Cloneable`

`Serializable`

Subclasses of `SchedulingParameters` (`PriorityParameters`¹¹⁹, `ImportanceParameters`¹²⁰, and any others defined for particular schedulers) provide the parameters to be used by the `Scheduler`¹²¹. Changes to the values in a parameters object affects the scheduling behavior of all the `Schedulable`¹²² objects to which it is bound.

6.4.2.13.1 Constructors

SchedulingParameters

Signature

`protected`

`SchedulingParameters()`

Create a new instance of `SchedulingParameters`.

6.4.2.13.2 Methods

clone

Signature

`public`

`java.lang.Object clone()`

Return a clone of `this`. This method should behave effectively as if it constructed a new object with clones of the high-resolution time values of `this`.

- The new object is in the current allocation context.

¹¹⁹Section 6.4.2.6

¹²⁰Section 6.4.2.4

¹²¹Section 6.4.2.11

¹²²Section 6.4.1.3

- `clone` does not copy any associations from `this` and it does not implicitly bind the new object to a SO.
- The new object has clones of all high-resolution time values (deep copy).
- References to event handlers are copied (shallow copy.)

6.4.2.14 SporadicParameters

Inheritance

```

java.lang.Object
  javafx.realtime.ReleaseParameters
    javafx.realtime.AperiodicParameters
      javafx.realtime.SporadicParameters

```

A notice to the scheduler that the associated schedulable's run method will be released aperiodically but with a minimum time between releases.

When a reference to a **SporadicParameters** object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's setter methods, the **SporadicParameters** object becomes the release parameters object bound to that schedulable. Changes to the values in the **SporadicParameters** object affect that schedulable object. When bound to more than one schedulable then changes to the values in the **SporadicParameters** object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

The implementation must use modified copy semantics for each **HighResolutionTime**¹²³ parameter value. The value of each time object should be treated as when it were copied at the time it is passed to the parameter object, but the object reference must also be retained. Only changes to a **SporadicParameters** object caused by methods on that object cause the change to propagate to all schedulables using the parameter object. For instance, calling `setCost` on a **SporadicParameters** object will make the change, then notify that the scheduler that the parameter object has changed. At that point the object is reconsidered for every SO that uses it. Invoking a method on the **RelativeTime** object that is the cost for this object may change the cost but it does not pass the change to the scheduler at that time. That change must not change the behavior of the SOs that use the parameter object until a setter method on the **SporadicParameters** object is invoked, or the parameter object is used in `setReleaseParameters()` or a constructor for an SO.

The following table gives the default parameter values for the constructors.

This class enables the application to specify one of four possible behaviors that indicate what to do when an arrival occurs that is closer in time to the previous

¹²³Section 9.4.1.2

Table 6.9: SporadicParameters Default Values

Attribute	Value
minInterarrival time	No default. A value must be supplied
cost	new RelativeTime(0,0)
deadline	new RelativeTime(mit)
overrunHandler	None
missHandler	None
MIT violation policy	SAVE
Arrival queue overflow policy	SAVE
Initial arrival queue length	0

arrival than the value given in this class as minimum interarrival time, what to do when, for any reason, the queue overflows, and the initial size of the queue.

6.4.2.14.1 Fields

mitViolationExcept

```
public static final mitViolationExcept
```

Represents the “EXCEPT” policy for dealing with minimum interarrival time violations. Under this policy, when an arrival time for any instance of [Schedulable](#)¹²⁴ which has `this` as its instance of [ReleaseParameters](#)¹²⁵ occurs at a time less than the minimum interarrival time defined here then the `fire()` method shall throw [MITViolationException](#)¹²⁶. Any other associated semantics are governed by the schedulers for the schedulables using these sporadic parameters. When the arrival time is a result of a happening to which the instance of [AsyncEventHandler](#)¹²⁷ is bound then the arrival time is ignored.

mitViolationIgnore

¹²⁴Section [6.4.1.3](#)

¹²⁵Section [6.4.2.9](#)

¹²⁶Section [14.3.2.6](#)

¹²⁷Section [8.4.3.5](#)

```
public static final mitViolationIgnore
```

Represents the “IGNORE” policy for dealing with minimum interarrival time violations. Under this policy, when an arrival time for any instance of [Schedulable](#)¹²⁸ which has `this` as its instance of [ReleaseParameters](#)¹²⁹ occurs at a time less than the minimum interarrival time defined here then the new arrival time is ignored. Any other associated semantics are governed by the schedulers for the schedulables using these sporadic parameters.

mitViolationSave

```
public static final mitViolationSave
```

Represents the “SAVE” policy for dealing with minimum interarrival time violations. Under this policy the arrival time for any instance of [Schedulable](#)¹³⁰ which has `this` as its instance of [ReleaseParameters](#)¹³¹ is not compared to the specified minimum interarrival time. Any other associated semantics are governed by the schedulers for the schedulable objects using these sporadic parameters.

mitViolationReplace

```
public static final mitViolationReplace
```

Represents the “REPLACE” policy for dealing with minimum interarrival time violations. Under this policy when an arrival time for any instance of [Schedulable](#)¹³² which has `this` as its instance of [ReleaseParameters](#)¹³³ occurs at a time less than the minimum interarrival time defined here then the information for this arrival replaces a previous arrival. Any other associated semantics are governed by the schedulers for the schedulables using these sporadic parameters.

6.4.2.14.2 Constructors

SporadicParameters(RelativeTime)

¹²⁸Section [6.4.1.3](#)

¹²⁹Section [6.4.2.9](#)

¹³⁰Section [6.4.1.3](#)

¹³¹Section [6.4.2.9](#)

¹³²Section [6.4.1.3](#)

¹³³Section [6.4.2.9](#)

Signature

```
public  
SporadicParameters(RelativeTime minInterarrival)
```

Create a `SporadicParameters` object. This constructor is equivalent to:
`SporadicParameters(minInterarrival, null, null, null, null, false)`

SporadicParameters(RelativeTime, RelativeTime)*Signature*

```
public  
SporadicParameters(RelativeTime minInterarrival,  
                   RelativeTime deadline)
```

Create a `SporadicParameters` object. This constructor is equivalent to:
`SporadicParameters(minInterarrival, null, deadline, null, null, false)`

SporadicParameters(RelativeTime, RelativeTime, AsyncEventHandler, boolean)*Signature*

```
public  
SporadicParameters(RelativeTime minInterarrival,  
                   RelativeTime deadline,  
                   AsyncEventHandler missHandler,  
                   boolean rousable)
```

Create a `SporadicParameters` object. This constructor is equivalent to:
`SporadicParameters(minInterarrival, null, deadline, null, missHandler)`

SporadicParameters(RelativeTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)*Signature*

```
public  
SporadicParameters(RelativeTime minInterarrival,  
                   RelativeTime cost,
```

```
RelativeTime deadline,  
AsyncEventHandler overrunHandler,  
AsyncEventHandler missHandler)
```

Create a `SporadicParameters` object.

Parameters

minInterarrival The release times of the schedulable will occur no closer than this interval. This time object is treated as if it were copied. Changes to **minInterarrival** will not effect the `SporadicParameters` object. There is no default value. When **minInterarrival** is `null` an illegal argument exception is thrown.

cost Processing time per release. On implementations which can measure the amount of time a schedulable is executed, this value is the maximum amount of time a schedulable receives per release. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When `null`, the default value is a new instance of `RelativeTime(mit)`.

overrunHandler This handler is invoked when an invocation of the schedulable exceeds **cost**. Not required for minimum implementation. When `null` no overrun handler will be used.

missHandler This handler is invoked when the `run()` method of the schedulable is still executing after the deadline has passed. When `null`, no deadline miss handler will be used.

Throws

`IllegalArgumentException` when **minInterarrival** is `null` or its time value is not greater than zero, or the time value of **cost** is less than zero, or the time value of **deadline** is not greater than zero, or when the clocks associated with **deadline** and **minInterarrival** parameters are not identical.

`IllegalAssignmentError` when **minInterarrival**, **cost**, **deadline**, **overrunHandler** or **missHandler** cannot be stored in this.

SporadicParameters(RelativeTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler, boolean)

Signature

```
public  
SporadicParameters(RelativeTime minInterarrival,
```

```

    RelativeTime cost,
    RelativeTime deadline,
    AsyncEventHandler overrunHandler,
    AsyncEventHandler missHandler,
    boolean rousable)

```

Create a `SporadicParameters` object.

Parameters

minInterarrival The release times of the schedulable will occur no closer than this interval. This time object is treated as if it were copied. Changes to **minInterarrival** will not effect the `SporadicParameters` object. There is no default value. When **minInterarrival** is `null` an illegal argument exception is thrown.

cost Processing time per release. On implementations which can measure the amount of time a schedulable is executed, this value is the maximum amount of time a schedulable receives per release. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When `null`, the default value is a new instance of `RelativeTime(mit)`.

overrunHandler This handler is invoked when an invocation of the schedulable exceeds **cost**. Not required for minimum implementation. When `null` no overrun handler will be used.

missHandler This handler is invoked when the `run()` method of the schedulable is still executing after the deadline has passed. When `null`, no deadline miss handler will be used.

rousable determines whether or not an instance of `Schedulable` can be prematurely released by a thread interrupt.

Throws

`IllegalArgumentException` when **minInterarrival** is `null` or its time value is not greater than zero, or the time value of **cost** is less than zero, or the time value of **deadline** is not greater than zero, or when the clocks associated with **deadline** and **minInterarrival** parameters are not identical.

`IllegalAssignmentError` when **minInterarrival**, **cost**, **deadline**, **overrunHandler** or **missHandler** cannot be stored in **this**.

6.4.2.14.3 Methods

setMitViolationBehavior(String)

Signature

```
public  
void setMitViolationBehavior(String behavior)
```

Sets the behavior of the arrival time queue in the case where the new arrival time is closer to the previous arrival time than the minimum interarrival time given in this.

Values of `behavior` are compared using reference equality (`==`) not value equality (`equals()`).

Parameters

`behavior` A string representing the behavior.

Throws

`IllegalArgumentException` when `behavior` is not one of the final MIT violation behavior values defined in this class.

getMitViolationBehavior

Signature

```
public  
java.lang.String getMitViolationBehavior()
```

Gets the arrival time queue behavior in the event of a minimum interarrival time violation.

Returns

The minimum interarrival time violation behavior as a string.

getMinimumInterarrival

Signature

```
public  
javax.realtime.RelativeTime getMinimumInterarrival()
```

Gets the minimum interarrival time.

Returns

The minimum interarrival time.

setMinimumInterarrival(RelativeTime)

Signature

```
public  
void setMinimumInterarrival(RelativeTime minimum)
```

Set the minimum interarrival time.

Parameters

minimum The release times of the schedulable will occur no closer than this interval.

Throws

IllegalArgumentException when **minimum** is null or its time value is not greater than zero.

IllegalAssignmentError when **minimum** cannot be stored in **this**.

6.5 Rationale

As specified, the required semantics of this section establish a scheduling policy that is very similar to the scheduling policies found on the vast majority of realtime operating systems and kernels in commercial use today. The semantics for the base scheduler accommodate existing practice, which is a stated goal of the effort.

There is an important division between priority schedulers that force periodic context switching between tasks at the same priority, and those that do not cause these context switches. By not specifying time slicing[1] behavior this specification calls for the latter type of priority scheduler. In POSIX terms, **SCHED_FIFO** meets the **RTSJ** requirements for the base scheduler, but **SCHED_RR** does not meet those requirements.

Although a system may not implement the first release (start) of a schedulable as unblocking that schedulable, under the base scheduler those semantics apply; i.e., the schedulable is added to the tail of the queue for its active priority.

Some research shows that, given a set of reasonable common assumptions, 32 distinct priority levels are a reasonable choice for close-to-optimal scheduling efficiency when using the rate-monotonic priority assignment algorithm on a single processor system (256 priority levels provide better efficiency). This specification requires at least 28 distinct priority levels as a compromise noting that implementations of this specification will exist on systems with logic executing outside of the Java Virtual Machine and may need priorities above, below, or both for system activities.

The default behavior for implementations that support cost monitoring and enforcement is that a schedulable receives no more than **cost** units of CPU time during each release. The programmer must explicitly change the cost attribute to override

the scheduler. The RTSJ allows schedulables to self suspend during a release, in addition to that which might be necessary to acquire a lock. These self suspensions must be time bounded. Any self suspension which is not time bounded may undermine the cost enforcement model specified in this document, as it may result in a schedulable suspending beyond its next release event. This can result in more time being allocated than any associated schedulability analysis might assume. See Dos Santos and Wellings for a full discussion on the problem [4].

Cost enforcement may be deferred while the overrun schedulable holds locks that are out of application control, such as locks used to protect garbage collection. Applications should include the resulting jitter in any analysis that depends on cost enforcement.

When a schedulable is enforced because of cost overrun in a processing group the enforced priority is used for scheduling instead of the schedulable's base priority. The enforced priority's application is limited. The enforced priority is not returned as the schedulable's priority from methods such as `getPriority()`, and the semantics of the active priority continue to operate when a schedulable is enforced.

6.5.1 Multiprocessor Support

The support that the RTSJ provides for multiprocessor systems is primarily constrained by the support it can expect from the underlying operating system. The following have had the most impact on the level of support that has been specified.

- The notion of processor *affinity* is common across operating systems and has become the accepted way to specify the constraints on which processor a thread can execute. In some sense, processor affinities can be viewed as additional release or scheduling parameters. However, to add them to the parameter classes requires the support to be distributed throughout the specification with a proliferation of new constructor methods. To avoid this, support is grouped together within the `Affinity` class. The class also provides the addition of processor affinity support to Java threads without modifying the thread object's visible API.
- The range of processors on which global scheduling is possible is dictated by the operating system. For SMP architectures, global scheduling across all the processors in the system is typically supported. However, an application and an operator can constrain threads and processes to execute only within a subset of the processors. As the number of processors increase, the scalability of global scheduling is called into question. Hence, for NUMA architectures some partitioning of the processors is likely to be performed by the OS. Hence, global scheduling across all processors will not be possible in these systems. For these reasons, the RTSJ supports an array of *predefined* affinities. These are implementation-defined. They can be used either to reflect the scheduling

arrangement of the underlying OS or they can be used by the system designer to impose defaults for, say, Java threads, non-heap realtime schedulables etc. A program is only allowed to dynamically create new affinities with cardinality of one. This restriction reflects the concern that not all operating systems will support multiprocessor affinities.

- Many OSs give system operators command-level dynamic control over the set of processors allocated to a processes. Consequently, the realtime JVM has no control over whether processors are dynamically added or removed from its OS process. Predictability is a prime concern of the RTSJ. Clearly, dynamic changes to the allocated processors will have a dramatic, and possibly catastrophic, effect on the ability of the program to meet timing requirements. Hence, the RTSJ assumes that the processor set allocated to the RTSJ process does not change during its execution. A system that is capable of such manipulations should not exercise it on RTSJ processes.
- The reason the expert group decided not to add affinities to scheduling parameters is that ASEH do not have a single server thread, hence forcing a particular affinity would complicate the implementation.

6.5.2 Impact of Clock Granularity

All time-triggered computation can suffer from release jitter. This is defined to be the variation in the actual time the computation becomes available for execution from its scheduled release time. The amount of release jitter depends on two factors. The first is the granularity of the clock/timer used to trigger the release. For example, a periodic event handler that is due to be released at absolute time T will actually be released at time $T + \delta$. δ is the difference between T and the first time the timer clock advances to T_0 , where $T_0 \geq T$. The upper bound of δ is the value returned from calling the `getResolution` method of the associated clock. It is for this reason that the implementation of release times for periodic activities must use absolute rather than relative time values, in order to avoid the drift accumulating.

The second contribution to release jitter is also related to the clock/timer. It is the duration of interval between T_0 being signaled by the clock/timer and the time this event is noticed by the underlying operating system or platform (perhaps because interrupts have been disabled). A compliant implementation of SCJ should document the maximum value of δ for the realtime clock.

6.5.3 Deadline Miss Detection

Although RTSJ supports deadline miss detection, it is important to understand the intrinsic limitations of the facility. The SCJ facility is supported using a time-triggered event. All time-triggered computation can suffer from release jitter. Hence,

any deadline miss handler may not be released until sometime after the deadline has expired. The handlers actual execution will depend on its priority relative to other schedulables.

A related limitation is that a deadline can be missed but not detected. This can occur when the deadline has been set at a smaller granularity than the detecting timer. Consider an absolute deadline of D . Suppose that the next absolute time that the timer can recognize is $D + \delta$. When the associate thread finishes after D but before $D + \delta$, it will have missed its deadline, but this miss will have been undetected.

A third limitation is due to the inherent race condition that is present when checking for deadline misses. A deadline miss is defined to occur when a schedulable has not completed the computation associated with its release before its deadline. This completion event is signalled in the application code by the return of the `handleAsyncEvent` method or a call to `waitForNextRelease` etc. When this occurs, the infrastructure reschedules/cancels the timing event that signals the miss of a deadline. This is clearly a race condition. The timer event could fire between the last statement the completion event and the rescheduling/canceling of the timer event. Hence a deadline miss could be signalled when arguably the application had performed all of its computation.

Chapter 7

Synchronization

7.1 Overview

One of the strength of Java is its language support for multithreading. This requires synchronization. In a realtime system, there are additional requirement on this synchronization. Therefore this specification not only tightens the semantics of the synchronization declarations, but it also provides addition classes that specifically manage synchronization.

This specification strengthens the semantics of Java **synchronized** code by mandating monitor execution eligibility control, commonly referred to as priority inversion control. The **MonitorControl** class is defined as the superclass of all such execution eligibility control algorithms. Its subclasses **PriorityInheritance** and **PriorityCeilingEmulation** avoid unbounded priority inversions, which would be unacceptable in realtime systems.

The classes described below provide two main services.

- They enable the setting of a priority inversion control policy either as the default or for specific objects.
- They also provide wait-free communication between schedulables (especially instances of **Schedulable**, whose **mayUseHeap** is **false**) and regular Java threads.

These classes establish a framework for priority inversion management that applies to priority-oriented schedulers in general, and a specific set of requirements for the base priority scheduler. The wait-free queue classes provide safe, concurrent access to data shared between instances of realtime thread without heap access and schedulable objects subject to garbage collection delays.

7.2 Definitions

Scheduling Eligibility Inversion is when a more important task is blocked by a less important task. This is usually caused by synchronization, where a more important task must wait for a less important task to release a required resource, which can in turn be blocked by a task of intermediate importance. The classical example in priority inversion in a system with a priority-based scheduler.

An object **A**, that has been assigned (either by default or via an explicit method call) to the **MonitorControlPolicy** α , then **A** is said to be *governed by* α .

7.3 Semantics

Synchronization semantics has two main aspects: the monitor control and scheduling. The first determines which inversion avoidance is to use. The second determines how it is done. Since, only priority-based schedulers are defined in the RTSJ, the semantics is only completely defined for priority-based schedulers.

7.3.1 Monitor Control

The specification provides for two monitor control policies with the following semantics.

1. The initial default monitor control policy shall be **PriorityInheritance**. The default policy can be altered by using the **setMonitorControl()** method.
2. Notwithstanding the preceding rule, an RTSJ implementation may allow the program to establish a different initial default monitor control policy at JVM startup. The program can query the initial default monitor control policy via the method **RealtimeSystem.getInitialMonitorControl**.
3. The **PriorityCeilingEmulation** monitor control policy is also required.
4. An implementation that provides any additional **MonitorControl** subclasses must document their effects, particularly with respect to priority inversion control.
5. An object's monitor control policy affects *each* entity that attempts to lock the object; i.e., regular Java threads as well as schedulables.
6. When a task, thread or schedulable, enters synchronized code, the target object's monitor control policy must be supported by the thread or schedulable's scheduler; otherwise an **IllegalThreadStateException** is thrown. An implementation that defines a new **MonitorControl** subclass must document which (if any) schedulers do not support this policy.

7.3.2 Priority Schedulers

The two schedulers provided by the RTSJ must both handle synchronization in the same way. All tasks governed by these schedulers are subject to the following semantics when they synchronize on objects governed by monitor control policies defined in this section.

1. Each thread or schedulable has a *base priority* and an *active priority*. A thread or schedulable that holds a lock on a PCE-governed object also has a *ceiling priority*.
2. The *base priority* for a thread or schedulable t is initially the priority that t has when it is created. The base priority is updated (immediately) as an effect of invoking any of the following methods:
 - (a) `pparam.setPriority(prio)`, where t is a schedulable with `pparams` as its `SchedulingParameters` and `pparams` is an instance of `PriorityParameters` or one of its subclasses; the new base priority is `prio`
 - (b) `t.setSchedulingParameters(pparams)`, where t is a schedulable and `pparams` is an instance of `PriorityParameters`; the new base priority is `pparams.getPriority()`
 - (c) `t.setPriority(prio)`, when t is a schedulable object, the new base priority is `prio` and when it is a Java thread, the new base priority is the lesser of `prio`, and the maximum priority for t 's thread group.
3. When the task t does not hold any locks, its active priority is the same as its base priority. In such a situation, modification of the priority of t through an invocation of any of the above priority-setting methods for t causes t to be placed at the tail of its relevant queue (ready, blocked on a particular object, etc.) at its new priority, when the new priority is higher than the old priority, and at the beginning otherwise.
4. When task t holds one or more locks, then t has a set of *priority sources*. The *active priority* for t at any point in time is the maximum of the priorities associated with all of these sources. The priority sources resulting from the monitor control policies defined in this section, and their associated priorities for a schedulable t , are as follows:
 - (a)

<i>Source</i>	t itself
<i>Associated Priority</i>	The base priority for t
<i>Note</i>	This may have been changed (either synchronously or asynchronously) while t has been holding its lock(s).
 - (b)

- | | | |
|-----|----------------------------|--|
| | <i>Source</i> | Each object locked by t and governed by a PriorityCeilingEmulation policy |
| | <i>Associated Priority</i> | The maximum value ceil , where ceil is the ceiling of a PriorityCeilingEmulation policy governing an object locked by t . |
| | <i>Note</i> | This value is also referred to as the <i>ceiling priority</i> for t . |
| (c) | <i>Source</i> | Each task attempting to synchronize on an object locked by t and governed by a PriorityInheritance policy |
| | <i>Associated Priority</i> | The maximum active priority over all such threads and schedulables |
| | <i>Note</i> | This rule accounts for recursive priority inheritance. |
| (d) | <i>Source</i> | Each task attempting to synchronize on an object locked by t and governed by a PriorityCeilingEmulation policy. |
| | <i>Associated Priority</i> | The maximum active priority over all such threads and schedulables |
| | <i>Note</i> | This rule, which in effect allows a PriorityCeilingEmulation lock to behave like a PriorityInheritance lock, helps avoid unbounded priority inversions that could otherwise occur in the presence of nested synchronizations involving a mix of PriorityCeilingEmulation and PriorityInheritance policies. |
5. The addition of a priority source for t either leaves t 's active priority unchanged, or increases it. When t 's active priority is unchanged, t 's status in its relevant queue(s), e.g., blocked waiting for some object, is not affected. When t 's active priority is increased, t is placed at the tail of the relevant queue(s) at its new active priority level.
 6. The removal of a priority source for T either leaves T 's active priority unchanged, or decreases it. When T 's active priority is unchanged, then T 's status in its relevant queue, e.g., blocked waiting for some object, is not affected. When T 's active priority is decreased and T is either ready or running, then T must be placed at the head of the ready queue at its new active priority level. When T 's active priority is decreased and T is blocked, then T is queued at the end of the queue for the new priority when it become unblocked.

The above rules have four main consequences.

1. A thread or schedulable t 's priority sources from 4b are added and removed synchronously; i.e., they are established based on t 's entering or leaving synchronized code. However, priority sources from 4a, `refsync:inherit`, and 4d may

be added and removed asynchronously, as an effect of actions by other threads or schedulables.

2. A task holding only one lock, when it releases this lock, has its active priority set to its base priority.
3. A task's active priority is never less than its base priority.
4. When a task blocks at a call of `obj.wait()`, it releases the lock on `obj` and hence relinquishes the priority source(s) based on `obj`'s monitor control policy. The task will be queued at a new active priority that reflects the loss of these priority sources.

Since base priorities may be shared (i.e., the same `PriorityParameters` object may be associated with multiple schedulables), a given base priority may be the active priority for some but not all of its associated schedulables. It is a consequence of other rules that, when a thread or schedulable `t` attempts to synchronize on an object `obj` governed by a `PriorityCeilingEmulation` policy with ceiling `ceil`, then `t`'s active priority may exceed `ceil` but `t`'s base priority must not. In contrast, once `t` has successfully synchronized on `obj`, then `t`'s base priority may also exceed `obj`'s monitor control policy's ceiling. Note that either or both of `t`'s base priority and `obj`'s monitor control policy may have been dynamically modified.

7.3.3 Additional Schedulers

Schedulers based on criteria other than priority, for example, deadline in a deadline first scheduler, must consider how synchronization is handled to avoid scheduling eligibility inversion. Such a scheduler must conform to the following semantics for tasks managed by that scheduler when they synchronize on objects with the monitor control policies defined above.

1. An implementation that defines a new `Scheduler` subclass must document which (if any) monitor control policies the new scheduler does not support.
2. An implementation must document how, if at all, the semantics of synchronization differ from the rules defined for the default `PriorityInheritance` instance and for the `PriorityCeilingEmulation` policy. It must supply documentation for the behavior of the new scheduler with priority inheritance and priority ceiling emulation protocol equivalent to the semantics for the default priority scheduler found in the previous section.

7.4 Package javax.realtime

7.4.1 Classes

7.4.1.1 MonitorControl

Inheritance

java.lang.Object
 javax.realtime.MonitorControl

Abstract superclass for all monitor control policy objects.

7.4.1.1.1 Constructors

MonitorControl

Signature

```
protected  
MonitorControl()
```

Invoked from subclass constructors.

7.4.1.1.2 Methods

getMonitorControl(Object)

Signature

```
public static  
javax.realtime.MonitorControl getMonitorControl(Object obj)
```

Gets the monitor control policy of the given instance of `Object`.

Parameters

`obj` The object being queried.

Throws

`IllegalArgumentException` when `obj` is null.

Returns

The monitor control policy of the `obj` parameter.

getMonitorControl*Signature*

```
public static  
javax.realtime.MonitorControl getMonitorControl()
```

Gets the current default monitor control policy.

Returns

The default monitor control policy object.

setMonitorControl(MonitorControl)*Signature*

```
public static  
javax.realtime.MonitorControl setMonitorControl(MonitorControl policy)
```

Sets the *default monitor control policy*. This policy does not affect the monitor control policy of any already created object, it will, however, govern any object subsequently constructed, until either:

1. a new "per-object" policy is set for that object. This will alter the monitor control policy for a single object without changing the default policy.
2. a new default policy is set.

Like the per-object method (see [setMonitorControl\(Object, MonitorControl\)](#)¹, the setting of the default monitor control policy occurs immediately.

Parameters

`policy` The new monitor control policy. When `null` nothing happens.

Throws

`SecurityException` when the caller is not permitted to alter the default monitor control policy.

`IllegalArgumentException` when `policy` is not in immortal memory.

`UnsupportedOperationException` when `policy` is not a supported monitor control policy.

Returns

The default `MonitorControl` policy that was replaced.

¹Section [7.4.1.1.2](#)

setMonitorControl(Object, MonitorControl)

Signature

```
public static  
javax.realtime.MonitorControl setMonitorControl(Object obj,  
                                                MonitorControl policy)
```

Immediately sets `policy` as the monitor control policy for `obj`.

A thread or schedulable that is queued for the lock associated with `obj`, or is in `obj`'s wait set, is not rechecked (e.g., for a `CeilingViolationException`) under `policy`, either as part of the execution of `setMonitorControl` or when it is awakened to (re)acquire the lock.

The thread or schedulable invoking `setMonitorControl` must already hold the lock on `obj`.

Parameters

`obj` The object that will be governed by the new policy.

`policy` The new policy for the object. When `null` nothing will happen.

Throws

`IllegalArgumentException` Thrown when `obj` is `null` or `policy` is not in immortal memory.

`UnsupportedOperationException` when `policy` is not a supported monitor control policy.

`IllegalMonitorStateException` when the caller does not hold a lock on `obj`.

Returns

The current `MonitorControl` policy for `obj`, which will be replaced.

7.4.1.2 PriorityCeilingEmulation

Inheritance

```
java.lang.Object  
  javax.realtime.MonitorControl  
    javax.realtime.PriorityCeilingEmulation
```

Monitor control class specifying the use of the priority ceiling emulation protocol (also known as the "highest lockers" protocol). Each `PriorityCeilingEmulation` instance is immutable; it has an associated *ceiling*, initialized at construction and queryable but not updatable thereafter.

When a thread or schedulable synchronizes on a target object governed by a `PriorityCeilingEmulation` policy, then the target object becomes a priority source

for the thread or schedulable object. When the object is unlocked, it ceases serving as a priority source for the thread or schedulable. The practical effect of this rule is that the thread or schedulable's active priority is boosted to the policy's ceiling when the object is locked, and is reset when the object is unlocked. The value that it is reset to may or may not be the same as the active priority it held when the object was locked; this depends on other factors (e.g. whether the thread or schedulable's base priority was changed in the interim).

The implementation must perform the following checks when a thread or schedulable `t` attempts to synchronize on a target object governed by a `PriorityCeilingEmulation` policy with ceiling `ceil`:

- `t`'s base priority does not exceed `ceil`
- `t`'s ceiling priority (when `t` is holding any other `PriorityCeilingEmulation` locks) does not exceed `ceil`.

Thus for any object `targetObj` that will be governed by priority ceiling emulation, the programmer needs to provide (via `MonitorControl.setMonitorControl(Object, MonitorControl)`²) a `PriorityCeilingEmulation` policy whose ceiling is at least as high as the maximum of the following values:

- the highest base priority of any thread or schedulable that could synchronize on `targetObj`
- the maximum ceiling priority value that any thread or schedulable object could have when it attempts to synchronize on `targetObj`.

More formally:

- When a thread or schedulable `t` whose base priority is `p1` attempts to synchronize on an object governed by a `PriorityCeilingEmulation` policy with ceiling `p2`, where `p1 > p2`, then a `CeilingViolationException` is thrown in `t`. A `CeilingViolationException` is likewise thrown in `t` when `t` is holding a `PriorityCeilingEmulation` lock and has a ceiling priority exceeding `p2`.

The values of `p1` and `p2` are passed to the constructor for the exception and may be queried by an exception handler.

A consequence of the above rule is that a thread or schedulable may nest synchronizations on `PriorityCeilingEmulation`-governed objects as long as the ceiling for the inner lock is not less than the ceiling for the outer lock.

The possibility of nested synchronizations on objects governed by a mix of `PriorityInheritance` and `PriorityCeilingEmulation` policies requires one other piece of behavior in order to avoid unbounded priority inversions. When a thread or schedulable holds a `PriorityInheritance` lock, then any `PriorityCeilingEmulation` lock that it either holds or attempts to acquire will exhibit priority inheritance characteristics. This rule is captured above in the definition of priority sources (4.d).

²Section 7.4.1.1.2

When a thread or schedulable `t` attempts to synchronize on a `PriorityCeilingEmulation`-governed object with ceiling `ceil`, then `ceil` must be within the priority range allowed by `t`'s scheduler; otherwise, an `IllegalThreadStateException` is thrown. Note that this does not prevent a regular Java thread from synchronizing on an object governed by a `PriorityCeilingEmulation` policy with a ceiling higher than 10.

The priority ceiling for an object `obj` can be modified by invoking `MonitorControl.setMonitorControl(obj, newPCE)` where `newPCE`'s ceiling has the desired value.

See also [MonitorControl](#)³ [PriorityInheritance](#)⁴, and [CeilingViolationException](#)⁵.

7.4.1.2.1 Methods

instance(int)

Signature

```
public static
    javafx.realtime.PriorityCeilingEmulation instance(int ceiling)
```

Return a `PriorityCeilingEmulation` object with the specified ceiling. This object is in `ImmortalMemory`. All invocations with the same ceiling value return a reference to the same object.

Parameters

`ceiling` Priority ceiling value.

Throws

`IllegalArgumentException` when `ceiling` is outside of the range of permitted priority values (e.g., less than `PriorityScheduler.instance().getMinPriority()` or greater than `PriorityScheduler.instance().getMaxPriority()` for the base scheduler).

getCeiling

Signature

³Section [7.4.1.1](#)

⁴Section [7.4.1.3](#)

⁵Section [14.3.2.2](#)

```
public
int getCeiling()
```

Gets the priority ceiling for this `PriorityCeilingEmulation` object.

Returns

The priority ceiling.

getMaxCeiling

Signature

```
public static
javax.realtime.PriorityCeilingEmulation getMaxCeiling()
```

Gets a `PriorityCeilingEmulation` object whose ceiling is `PriorityScheduler.instance().getMaxPriorityCeiling()`. This method returns a reference to a `PriorityCeilingEmulation` object allocated in immortal memory. All invocations of this method return a reference to the same object.

Returns

A `PriorityCeilingEmulation` object whose ceiling is `PriorityScheduler.instance().getMaxPriorityCeiling()`.

7.4.1.3 PriorityInheritance

Inheritance

```
java.lang.Object
  javax.realtime.MonitorControl
    javax.realtime.PriorityInheritance
```

Singleton class specifying use of the priority inheritance protocol. When a thread or schedulable `t1` attempts to enter code that is synchronized on an object `obj` governed by this protocol, and `obj` is currently locked by a lower-priority thread or schedulable `t2`, then

1. When `t1`'s active priority does not exceed the maximum priority allowed by `t2`'s scheduler, then `t1` becomes a priority source for `t2`; `t1` ceases to serve as a priority source for `t2` when either `t2` releases the lock on `obj`, or `t1` ceases attempting to synchronize on `obj` (e.g., when `t1` incurs an ATC).
2. Otherwise (i.e., `t1`'s active priority exceeds the maximum priority allowed by `t2`'s scheduler), an `IllegalThreadStateException` is thrown in `t1`.

Note on the 2nd rule: throwing the exception in `t1`, rather than in `t2`, ensures that the exception is synchronous.

See also [MonitorControl](#)⁶ and [PriorityCeilingEmulation](#)⁷

7.4.1.3.1 Methods

instance

Signature

```
public static  
javax.realtime.PriorityInheritance instance()
```

Return a reference to the singleton `PriorityInheritance`.

This is the default `MonitorControl` policy in effect at system startup.

The `PriorityInheritance` instance shall be allocated in `ImmortalMemory`.

7.4.1.4 WaitFreeDequeue

Inheritance

```
java.lang.Object  
  javax.realtime.WaitFreeDequeue
```

A `WaitFreeDequeue` encapsulates a `WaitFreeWriteQueue` and a `WaitFreeReadQueue`. Each method on a `WaitFreeDequeue` corresponds to an equivalent operation on the underlying `WaitFreeWriteQueue` or `WaitFreeReadQueue`.

Incompatibility with V1.0: Three exceptions previously thrown by the constructor have been deleted from the `throws` clause. These are:

- `java.lang.IllegalAccessException`,
- `java.lang.ClassNotFoundException`, and
- `java.lang.InstantiationException`.

Including these exceptions on the `throws` clause was an error. Their deletion may cause compile-time errors in code using the previous constructor. The repair is to remove the exceptions from the `catch` clause around the constructor invocation.

`WaitFreeDequeue` is one of the classes allowing `NoHeapRealtimeThreads` and regular Java threads to synchronize on an object without the risk of a `NoHeapRealtimeThread` incurring Garbage Collector latency due to priority inversion avoidance management.

⁶Section [7.4.1.1](#)

⁷Section [7.4.1.2](#)

7.4.1.5 WaitFreeReadQueue

Inheritance

java.lang.Object
 javafx.runtime.WaitFreeReadQueue

A queue that can be non-blocking for consumers. The `WaitFreeReadQueue` class is intended for single-reader multiple-writer communication, although it may also be used (with care) for multiple readers. A *reader* is generally an instance of no-heap real-time thread, and the *writers* are generally regular Java threads or heap-using realtime threads or schedulables. Communication is through a bounded buffer of Objects that is managed first-in-first-out. The principal methods for this class are `write` and `read`

- The `write` method appends a new element onto the queue. It is synchronized, and blocks when the queue is full. It may be called by more than one writer, in which case, the different callers will write to different elements of the queue.
- The `read` method removes the oldest element from the queue. It is not synchronized and does not block; it will return `null` when the queue is empty. Multiple reader threads or schedulables are permitted, but when two or more intend to read from the same `WaitFreeWriteQueue` they will need to arrange explicit synchronization.

For convenience, and to avoid requiring a reader to poll until the queue is non-empty, this class also supports instances that can be accessed by a reader that blocks on queue empty. To obtain this behavior, the reader needs to invoke the `waitForData()` method on a queue that has been constructed with a `notify` parameter set to `true`.

`WaitFreeReadQueue` is one of the classes allowing no-heap real-time threads and regular Java threads to synchronize on an object without the risk of a no-heap real-time thread incurring Garbage Collector latency due to priority inversion avoidance management.

Incompatibility with V1.0: Three exceptions previously thrown by the constructor have been deleted. These are

- `java.lang.IllegalAccessException`,
- `java.lang.ClassNotFoundException`, and
- `java.lang.InstantiationException`.

These exceptions were in error. Their deletion may cause compile-time errors in code using the previous constructor. The repair is to remove the exceptions from the catch clause around the constructor invocation.

7.4.1.5.1 Constructors

WaitFreeReadQueue(Runnable, Runnable, int, MemoryArea, boolean)

Signature

```
public
WaitFreeReadQueue(Runnable writer,
                  Runnable reader,
                  int maximum,
                  MemoryArea memory,
                  boolean notify)
throws IllegalArgumentException,
    MemoryScopeException,
    InaccessibleAreaException
```

Constructs a queue containing up to **maximum** elements in **memory**. The queue has an unsynchronized and nonblocking **read()** method and a synchronized and blocking **write()** method.

The **writer** and **reader** parameters, when non-null, are checked to insure that they are compatible with the **MemoryArea** specified by **memory** (when non-null.) When **memory** is null and both **Runnables** are non-null, the constructor will select the nearest common scoped parent memory area, or when there is no such scope it will use immortal memory. When all three parameters are null, the queue will be allocated in immortal memory.

reader and **writer** are not necessarily the only threads or schedulable objects that will access the queue; moreover, there is no check that they actually access the queue at all.

Note: that the wait free queue's internal queue is allocated in **memory**, but the memory area of the wait free queue instance itself is determined by the current allocation context.

Parameters

- writer** An instance of **Runnable** or null.
- reader** An instance of **Runnable** or null.
- maximum** The maximum number of elements in the queue.
- memory** The **MemoryArea**⁸ in which internal elements are allocated.

⁸Section [11.4.2.3](#)

notify A flag that establishes whether a reader is notified when the queue becomes non-empty.

Throws

IllegalArgumentException when an argument holds an invalid value. The **writer** argument must be **null**, a reference to a **Thread**, or a reference to a schedulable (a **RealtimeThread**, or an **AsyncEventHandler**.) The **reader** argument must be **null**, a reference to a **Thread**, or a reference to a schedulable. The **maximum** argument must be greater than zero.

InaccessibleAreaException when **memory** is a scoped memory that is not on the caller's scope stack.

MemoryScopeException when either **reader** or **writer** is non-null and the **memory** argument is not compatible with **reader** and **writer** with respect to the assignment and access rules for memory areas.

WaitFreeReadQueue(Runnable, Runnable, int, MemoryArea)

Signature

```
public
WaitFreeReadQueue(Runnable writer,
                  Runnable reader,
                  int maximum,
                  MemoryArea memory)
throws IllegalArgumentException,
    MemoryScopeException,
    InaccessibleAreaException
```

Constructs a queue containing up to **maximum** elements in **memory**. The queue has an unsynchronized and nonblocking **read()** method and a synchronized and blocking **write()** method.

The **writer** and **reader** parameters, when non-null, are checked to insure that they are compatible with the **MemoryArea** specified by **memory** (when non-null.) When **memory** is **null** and both **Runnables** are non-null, the constructor will select the nearest common scoped parent memory area, or when there is no such scope it will use immortal memory. When all three parameters are **null**, the queue will be allocated in immortal memory.

reader and **writer** are not necessarily the only threads or schedulables that will access the queue; moreover, there is no check that they actually access the queue at all.

Note: that the wait free queue's internal queue is allocated in **memory**, but the memory area of the wait free queue instance itself is determined by the current allocation context.

Parameters

writer An instance of `Runnable` or `null`.

reader An instance of `Runnable` or `null`.

maximum The maximum number of elements in the queue.

memory The `MemoryArea`⁹ in which this object and internal elements are allocated.

Throws

`IllegalArgumentException` when an argument holds an invalid value. The **writer** argument must be `null`, a reference to a `Thread`, or a reference to a schedulable (a `RealtimeThread`, or an `AsyncEventHandler`.) The **reader** argument must be `null`, a reference to a `Thread`, or a reference to a schedulable. The **maximum** argument must be greater than zero.

`MemoryScopeException` when either **reader** or **writer** is non-null and the **memory** argument is not compatible with **reader** and **writer** with respect to the assignment and access rules for memory areas.

`InaccessibleAreaException` when **memory** is a scoped memory that is not on the caller's scope stack.

WaitFreeReadQueue(int, MemoryArea, boolean)

Signature

```
public
WaitFreeReadQueue(int maximum,
                   MemoryArea memory,
                   boolean notify)
throws IllegalArgumentException,
    InaccessibleAreaException
```

Constructs a queue containing up to **maximum** elements in **memory**. The queue has an unsynchronized and nonblocking `read()` method and a synchronized and blocking `write()` method.

Note: that the wait free queue's internal queue is allocated in **memory**, but the memory area of the wait free queue instance itself is determined by the current allocation context.

⁹Section 11.4.2.3

Parameters

maximum The maximum number of elements in the queue.

memory The [MemoryArea¹⁰](#) in which this object and internal elements are allocated.

notify A flag that establishes whether a reader is notified when the queue becomes non-empty.

Throws

IllegalArgumentException when the **maximum** argument is less than or equal to zero, or **memory** is null.

InaccessibleAreaException when **memory** is a scoped memory that is not on the caller's scope stack.

WaitFreeReadQueue(int, boolean)

Signature

```
public
WaitFreeReadQueue(int maximum,
                   boolean notify)
throws IllegalArgumentException
```

Constructs a queue containing up to **maximum** elements in immortal memory. The queue has an unsynchronized and nonblocking **read()** method and a synchronized and blocking **write()** method.

Parameters

maximum The maximum number of elements in the queue.

notify A flag that establishes whether a reader is notified when the queue becomes non-empty.

Throws

IllegalArgumentException when the **maximum** argument is less than or equal to zero.

7.4.1.5.2 Methods

clear

¹⁰Section [11.4.2.3](#)

Signature

```
public  
void clear()
```

Sets **this** to empty.

Note: This method needs to be used with care. Invoking **clear** concurrently with **read** or **write** can lead to unexpected results.

isEmpty*Signature*

```
public  
boolean isEmpty()
```

Queries the queue to determine if **this** is empty.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

true when **this** is empty; **false** when **this** is not empty.

isFull*Signature*

```
public  
boolean isFull()
```

Queries the system to determine if **this** is full.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

true when **this** is full; **false** when **this** is not full.

read*Signature*

```
public  
java.lang.Object read()
```

Reads the least recently inserted element from the queue and returns it as the result, unless the queue is empty. When the queue is empty, `null` is returned.

Returns

The `java.lang.Object` read, or else `null` when `this` is empty.

size

Signature

```
public  
int size()
```

Queries the queue to determine the number of elements in `this`.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

The number of positions in `this` occupied by elements that have been written but not yet read.

waitForData

Signature

```
public  
void waitForData()  
throws UnsupportedOperationException,  
    InterruptedException
```

When `this` is empty block until a writer inserts an element.

Note: When there is a single reader and no asynchronous invocation of `clear`, then it is safe to invoke `read` after `waitForData` and know that `read` will find the queue non-empty.

Implementation note: To avoid reader and writer synchronizing on the same object, the reader should not be notified directly by a writer. (This is the issue that the non-wait queue classes are intended to solve).

Throws

`UnsupportedOperationException` when `this` has not been constructed with `notify` set to `true`.

`InterruptedException` when the thread is interrupted by `interrupt()` or `AsynchronouslyInterruptedException.fire()`¹¹ during the time between

¹¹Section 8.4.2.1.2

calling this method and returning from it.

write(Object)

Signature

```
public synchronized  
void write(Object object)  
throws MemoryScopeException,  
        InterruptedException
```

A synchronized and blocking write. This call blocks on queue full and will wait until there is space in the queue.

Parameters

object The `java.lang.Object` that is placed in the queue.

Throws

`InterruptedException` when the thread is interrupted by `interrupt()` or `AsynchronouslyInterruptedException.fire()`¹² during the time between calling this method and returning from it.

`MemoryScopeException` when a memory access error or illegal assignment error would occur while storing **object** in the queue.

7.4.1.6 WaitFreeWriteQueue

Inheritance

```
java.lang.Object  
    javax.realtime.WaitFreeWriteQueue
```

A queue that can be non-blocking for producers. The `WaitFreeWriteQueue` class is intended for single-writer multiple-reader communication, although it may also be used (with care) for multiple writers. A *writer* is generally an instance of no-heap real-time thread, and the *readers* are generally regular Java threads or heap-using realtime threads or schedulables. Communication is through a bounded buffer of Objects that is managed first-in-first-out. The principal methods for this class are `write` and `read`.

- The `write` method appends a new element onto the queue. It is not synchronized, and does not block when the queue is full (it returns `false` instead). Multiple writer threads or schedulables are permitted, but when two or more

¹²Section 8.4.2.1.2

threads intend to write to the same `WaitFreeWriteQueue` they will need to arrange explicit synchronization.

- The `read` method removes the oldest element from the queue. It is synchronized, and will block when the queue is empty. It may be called by more than one reader, in which case the different callers will read different elements from the queue.

`WaitFreeWriteQueue` is one of the classes allowing no-heap real-time threads and regular Java threads to synchronize on an object without the risk of a no-heap real-time thread incurring Garbage Collector latency due to priority inversion avoidance management.

Incompatibility with V1.0: Three exceptions previously thrown by the constructor have been deleted from the `throws` clause. These are

- `java.lang.IllegalAccessException`,
- `java.lang.ClassNotFoundException`, and
- `java.lang.InstantiationException`.

Including these exceptions on the `throws` clause was an error. Their deletion may cause compile-time errors in code using the previous constructor. The repair is to remove the exceptions from the `catch` clause around the constructor invocation.

7.4.1.6.1 Constructors

`WaitFreeWriteQueue(Runnable, Runnable, int, MemoryArea)`

Signature

```
public
WaitFreeWriteQueue(Runnable writer,
                   Runnable reader,
                   int maximum,
                   MemoryArea memory)
throws IllegalArgumentException,
       MemoryScopeException,
       InaccessibleAreaException
```

Constructs a queue in memory with an unsynchronized and nonblocking `write()` method and a synchronized and blocking `read()` method.

The **writer** and **reader** parameters, when non-null, are checked to insure that they are compatible with the **MemoryArea** specified by **memory** (when non-null.) When **memory** is **null** and both **Runnable**s are non-null, the constructor will select the nearest common scoped parent memory area, or when there is no such scope it will use immortal memory. When all three parameters are **null**, the queue will be allocated in immortal memory.

reader and **writer** are not necessarily the only threads or schedulables that will access the queues; moreover, there is no check that they actually access the queue at all.

Note: that the wait free queue's internal queue is allocated in **memory**, but the memory area of the wait free queue instance itself is determined by the current allocation context.

Parameters

writer An instance of **Thread**, a schedulable object, or **null**.

reader An instance of **Thread**, a schedulable object, or **null**.

maximum The maximum number of elements in the queue.

memory The **MemoryArea**¹³ in which this object and internal elements are allocated.

Throws

IllegalArgumentException when an argument holds an invalid value. The **writer** argument must be **null**, a reference to a **Thread**, or a reference to a schedulable (a **RealtimeThread**, or an **AsyncEventHandler**.) The **reader** argument must be **null**, a reference to a **Thread**, or a reference to a schedulable. The **maximum** argument must be greater than zero.

MemoryScopeException when either **reader** or **writer** is non-null and the **memory** argument is not compatible with **reader** and **writer** with respect to the assignment and access rules for memory areas.

InaccessibleAreaException when **memory** is a scoped memory that is not on the caller's scope stack.

WaitFreeWriteQueue(int, MemoryArea)

Signature

```
public
WaitFreeWriteQueue(int maximum,
                    MemoryArea memory)
```

¹³Section 11.4.2.3

throws `IllegalArgumentException`,
`InaccessibleAreaException`

Constructs a queue containing up to `maximum` elements in `memory`. The queue has an unsynchronized and nonblocking `write()` method and a synchronized and blocking `read()` method.

Note: that the wait free queue's internal queue is allocated in `memory`, but the memory area of the wait free queue instance itself is determined by the current allocation context.

Parameters

`maximum` The maximum number of elements in the queue.

`memory` The `MemoryArea`¹⁴ in which this object and internal elements are allocated.

Throws

`IllegalArgumentException` when the `maximum` argument is less than or equal to zero, or `memory` is null.

`InaccessibleAreaException` when `memory` is a scoped memory that is not on the caller's scope stack.

WaitFreeWriteQueue(int)

Signature

```
public  
WaitFreeWriteQueue(int maximum)  
throws IllegalArgumentException
```

Constructs a queue containing up to `maximum` elements in immortal memory. The queue has an unsynchronized and nonblocking `write()` method and a synchronized and blocking `read()` method.

Parameters

`maximum` The maximum number of elements in the queue.

Throws

`IllegalArgumentException` when the `maximum` argument is less than or equal to zero.

7.4.1.6.2 Methods

¹⁴Section [11.4.2.3](#)

clear

Signature

```
public  
void clear()
```

Sets **this** to empty.

isEmpty

Signature

```
public  
boolean isEmpty()
```

Queries the system to determine if **this** is empty.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

True, when **this** is empty. False, when **this** is not empty.

isFull

Signature

```
public  
boolean isFull()
```

Queries the system to determine if **this** is full.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

True, when **this** is full. False, when **this** is not full.

read

Signature

```
public synchronized  
java.lang.Object read()
```


throws `InterruptedException`

A synchronized and possibly blocking operation on the queue.

Throws

`InterruptedException` when the thread is interrupted by `interrupt()` or `AsynchronouslyInterruptedException.fire()`¹⁵ during the time between calling this method and returning from it.

Returns

The `Object` least recently written to the queue. When `this` is empty, the calling thread or schedulable objects blocks until an element is inserted; when it is resumed, `read` removes and returns the element.

size

Signature

```
public
int size()
```

Queries the queue to determine the number of elements in `this`.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

The number of positions in `this` occupied by elements that have been written but not yet read.

force(Object)

Signature

```
public
boolean force(Object object)
throws MemoryScopeException,
        IllegalArgumentException
```

Unconditionally insert `object` into `this`, either in a vacant position or else overwriting the most recently inserted element. The `boolean` result reflects whether, at the time that `force()` returns, the position at which `object` was inserted was vacant (`false`) or occupied (`true`).

Parameters

¹⁵Section 8.4.2.1.2

`object` A non-null `java.lang.Object` to insert.

Throws

`MemoryScopeException` when a memory access error or illegal assignment error would occur while storing `object` in the queue.

`IllegalArgumentException` when `object` is `null`.

Returns

`true` when `object` has overwritten an element that was occupied when the function returns; `false` otherwise (it has been inserted into a position that was vacant when the function returns)

write(Object)

Signature

```
public
boolean write(Object object)
throws MemoryScopeException,
        IllegalArgumentException
```

Inserts `object` into `this` when `this` is non-full and otherwise has no effect on `this`; the `boolean` result reflects whether `object` has been inserted. When the queue was empty and one or more threads or schedulables were waiting to read, then one will be awakened after the write. The choice of which to awaken depends on the involved scheduler(s).

Parameters

`object` A non-null `java.lang.Object` to insert.

Throws

`MemoryScopeException` when a memory access error or illegal assignment error would occur while storing `object` in the queue.

`IllegalArgumentException` when `object` is `null`.

Returns

`true` when the queue was non-full; `false` otherwise.

7.5 Rationale

Java's rules for `synchronized` code provide a means for mutual exclusion but do not prevent unbounded priority inversions and thus are insufficient for realtime applications. This specification strengthens the semantics for `synchronized` code by mandating priority inversion control, in particular by furnishing classes for priority

inheritance and priority ceiling emulation. Priority inheritance is more widely implemented in realtime operating systems and thus is the initial default mechanism in this specification.

Priority ceiling emulation is also a useful protocol. It is necessary for blocking out interrupts in interrupt service routines and simplifies scheduling analysis for single core systems. Since it can easily be implemented in user space, it is required as well.

Since the same object may be accessed from synchronized code by both a no-heap real-time thread and an arbitrary thread or schedulable object, unwanted dependencies may result. To avoid this problem, this specification provides three wait-free queue classes as an alternative means for safe, concurrent data accesses without priority inversion.

Chapter 8

Asynchrony

8.1 Overview

One of the most important aspects of this specification is the support for asynchronous control flow. Mechanisms are provided for both starting a task asynchronously and interrupting the execution of a thread or other task. This specification provides mechanisms that

- bind the execution of program logic to the occurrence of internal and external events;
- enable asynchronous transfer of control; and
- facilitate the asynchronous termination of realtime threads.

The first of is provided by asynchronous event handling. Using this, an application can define some computation that is executed every time an event is “fired,” either from a clock or from some signal. The second is Asynchronous Transfer of Control (ATC), which provides a means of stopping some calculation prematurely. ATC may also be used to terminate a realtime thread safely.

8.1.1 Events and Event Handling

Asynchronous event handling is captured by the classes `AsyncBaseEvent` (AE), `AsyncBaseEventHandler` (AEH) and `AbstractBoundAsyncEventHandler`, along with their subclasses. An AE is an object used to direct event occurrences to asynchronous event handlers. An event occurrence may be initiated by application logic, by mechanisms internal to the RTSJ implementation (see the handlers in `PeriodicParameters`), or by some external input such as a clock, a signal, or an interrupt.

An asynchronous event occurrence is initiated in program logic by the invocation of the `fire` method of an AE. The `fire` method dispatches all handlers associated with its event. This means that dispatching occurs in the execution context of the caller.

An asynchronous event that is initiated from an external source has additional requirements and hence additional API features. These features are captured by the `ActiveEvent` interface. Since external events do not have a full execution context of their own, this category of events must provide an alternate execution context. In order to give the programmer control over this execution context, the specification defines the abstract class `ActiveEventDispatcher` to provide execution context for dispatching. Subclasses provide a `trigger` method for initiating dispatching. Triggering simply informs this execution context to start dispatching. The `trigger` method is not defined in `ActiveEventDispatcher`, since some classes need a `trigger` method with an argument and others do not. The types of `ActiveEvent` supported are described in subsequent chapters.

An AEH is a schedulable embodying code that is released for execution in response to the occurrence of an associated event. Each AEH behaves as if it is executed by a `RealtimeThread` except that it is not permitted to use the `waitForNextRelease()` method. There is not necessarily a separate realtime thread for each AEH, but the server realtime thread (returned by `currentRealtimeThread()`) remains constant during each execution of the `handleAsyncEvent()` method. The interface `BoundAsyncBaseEventHandler` is used to mark subclasses of `AsyncBaseEventHandler`, such as `BoundAsyncEventHandler`, which have a dedicated realtime server thread. Such a server thread is associated with one and only one bound AEH for the lifetime of that AEH. An event count (called `fireCount`) is maintained so that a handler can cope with event bursts—situations where an event occurs more frequently than its handler can respond.

8.1.2 Asynchronous Transfer of Control

The `interrupt()` method in `java.lang.Thread` provides rudimentary asynchronous communication by setting a pollable/resettable flag in the target thread, and by throwing a synchronous exception when the target thread is blocked at an invocation of `wait()`, `sleep()`, or `join()`. This specification generalizes the notion of `interrupt` to all `Schedulables`, offering a more comprehensive asynchronous execution control facility without requiring polling. For `RealtimeThreads`, the effect of `Thread.interrupt()` must be extended by adding an overridden version in `RealtimeThread`.

This new mechanism, called Asynchronous Transfer of Control (ATC), is based on throwing and propagating an exception that, though asynchronous, is deferred where necessary in order to avoid data structure corruption. The main elements of ATC are embodied in the class `AsynchronouslyInterruptedException`, its subclass `Timed`, the interface `Interruptible`, and in the semantics of the `interrupt` method in `Schedulable`.

A method indicates its eligibility for asynchronous interruption by including the

checked exception `AsynchronouslyInterruptedException` in its `throws` clause. If a schedulable is asynchronously interrupted while executing such a method, then an AIE will be delivered as soon as the schedulable is outside of a section in which ATC is deferred. Several idioms are available for handling an AIE, giving the programmer the choice of using `catch` clauses and a low-level mechanism with specific control over propagation, or a higher-level facility that enables specifying the interruptible code, the handler, and the result retrieval as separate methods.

8.2 Definitions

The following terms and abbreviations provide the vocabulary necessary for discussing the asynchronous facilities in the RTSJ.

AE—Asynchronous Event. An instance of one of the subclasses of the `javax.realtime.AsyncBase` class.

AEH—Asynchronous Event Handler. An instance of one of the subclasses of the `AsyncBaseEventHandler` class.

Bound AEH — Bound Asynchronous Event Handler. An instance of one of the subclasses of the `BoundAsyncBaseEventHandler` class.

ATC — Asynchronous Transfer of Control.

AIE — Asynchronously Interrupted Exception. An instance of the `javax.realtime.Asynchronous` class (a subclass of `java.lang.InterruptedException`).

AI-method - Asynchronously Interruptible method. A method or constructor that includes `AsynchronouslyInterruptedException` explicitly (that is not a subclass of `AsynchronouslyInterruptedException`) in its `throws` clause.

Lexical Scope [of a method, constructor, or statement]. The textual region within the constructor, method, or statement, excluding the code within any class declarations, and the code within any class instance creation expressions for anonymous classes, contained therein. The lexical scope of a construct does not include the bodies of any methods or constructors that this code invokes.

ATC-deferred section. A synchronized statement, a static initializer or any method or constructor without `AsynchronouslyInterruptedException` in its `throws` clause. As specified in the introduction to Chapter 8 in *Java Language Specification*, a synchronized method is equivalent to a non-synchronized method with the body of the method contained in a synchronized statement. Thus, a synchronized AI method behaves like an AI method containing only an ATC-deferred statement.

Interruptible blocking methods. The RTSJ and standard Java methods that are explicitly interruptible by an AIE. The interruptible blocking methods comprise

- `HighResolutionTime.waitForObject()`,
- `Object.wait()`,
- `Thread.sleep()`,

- `RealtimeThread.sleep()`,
- `Thread.join()`,
- `ScopedMemory.join()`,
- `ScopedMemory.joinAndEnter()`,
- `RealtimeThread.waitForNextRelease()`,
- `WaitFreeWriteQueue.read()`,
- `WaitFreeReadQueue.waitForData()`,
- `WaitFreeReadQueue.write()`,
- `WaitFreeDequeue.blockingRead()`,
- `WaitFreeDequeue.blockingWrite()`

and their overloaded forms.

8.3 Semantics

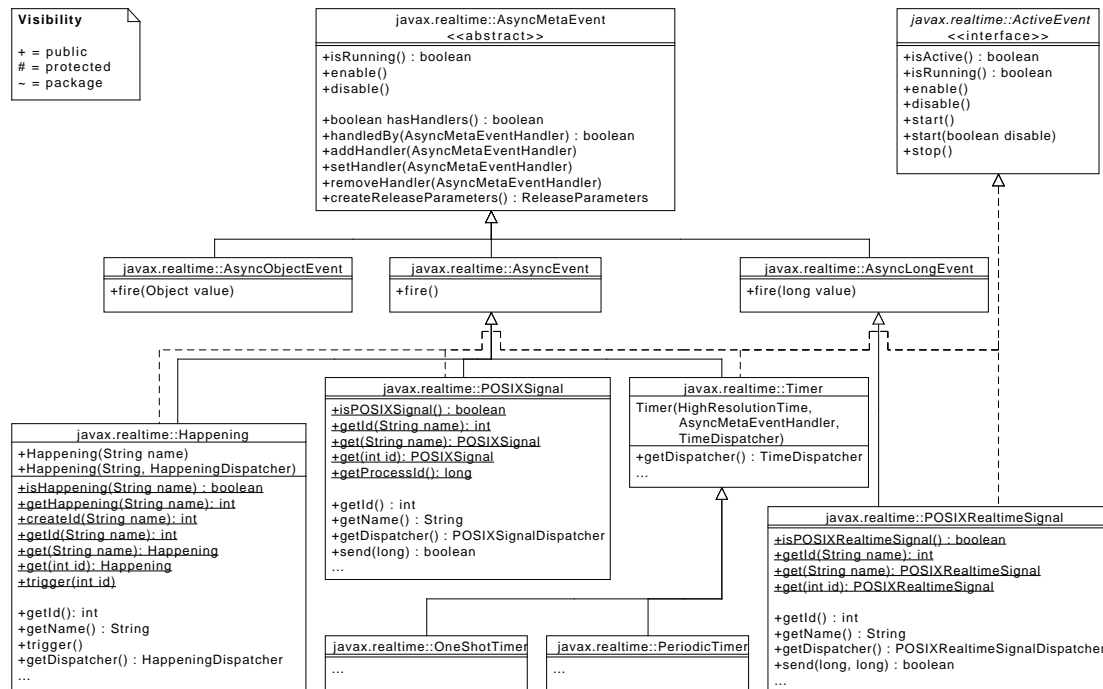
Asynchronous events and event handlers are required in the base module, whereas asynchronous transfer of control is optional. Basic event types are passive: they are not directly associated with a thread of control. They are intended to be fired programmatically. Handling external events, such as clocks (see Chapter 10) and happenings (see Chapter 12), requires an execution context. The `ActiveEvent` interface is provided to mark these and provide additional execution semantics. Figure 8.1 illustrates the event hierarchy.

8.3.1 Asynchronous Events and their Handlers

The following twelve points give the basic semantics for asynchronous events and their handlers. Semantics that apply to particular classes, constructors, methods, and fields are provided in the class description and the constructor, method, and field specifications.

1. When an asynchronous event occurs (by either program logic or by the triggering of a happening) and the event is enabled, its attached handlers (that is, AEHs that have been added to the AE by the execution of `addHandler()`) are released for execution. Every occurrence of an event increments the **fire-Count** in each attached handler. Handlers may elect to execute logic for each occurrence of the event or not.
2. The release of attached handlers occurs in execution eligibility order (priority order, from highest to lowest, with the default `PriorityScheduler`) and at the active priority of the schedulable that invoked the **fire** method. The release of handlers resulting from a happening or a timer must begin within a bounded time (ignoring time consumed by unrelated activities in the system).

Figure 8.1: The Event Class Hierarchy



This worst-case response interval must be documented for some reference architecture.

3. The release of attached handlers is an atomic operation with respect to adding and removing handlers.
4. The logical release of an attached handler may occur before the previous release has completed.
5. A deadline may be associated with each logical release of an attached handler. The deadline is relative to the occurrence of the associated event.
6. AEs and AEHs may be created and used by any program logic within the constraints of the memory assignment rules.
7. More than one AEH may be added to an AE. However, adding an AEH to an AE has no effect if the AEH is already attached to the AE.
8. The same AEH may be added to more than one AE.
9. By default all AEHs are considered to be daemons (the daemon status being set by their constructors). An AEH can be set to have a non daemon status after it has been created and before it has been attached to an AE.
10. The object returned by `currentRealtimeThread()` while an AEH is running shall behave with respect to memory access and assignment rules as if it were allocated in the same memory area as the AEH.

11. System-related termination activity (such as execution of finalizers for scoped objects in scopes that become unreferenced) triggered when an AEH becomes unfireable is not subject to cost enforcement or deadline miss detection.
12. AEs and AEHs behave effectively as if changes to an AEH's fireability are contained in synchronized blocks, and the AEH holds that lock while it is in the process of becoming non-fireable.

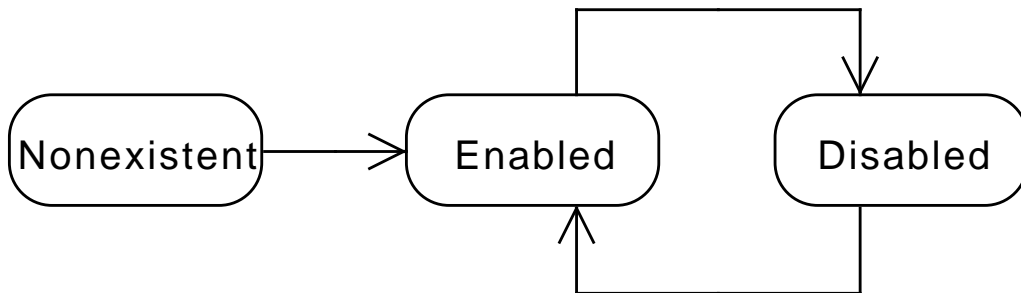
An RTSJ program terminates when and only when

- all non-daemon threads (either regular Java threads or realtime threads) are terminated,
- the **fireCounts** of all nondaemon bound AEHs or nondaemon AEHs are zero and all releases are completed, and
- there are no nondaemon Bound AEHs or AEHs attached to timers or async events associated with happenings.

Though dispatchers have a thread, this thread is a daemon thread and does not itself hinder termination.

AsyncBaseEvent provides two basic states: enabled and disabled. In the enabled state, fire causes all associated handlers to be dispatched, whereas fire does nothing when the event is disabled. Figure 8.2 illustrates this state space.

Figure 8.2: States of a Simple AsyncBaseEvent



8.3.2 Active Events and Dispatching

Active events refine the semantics of **AsyncBaseEventHandler** with the addition of execution semantics to support second level interrupt handling. The fire method of

an event runs in the Java execution context of the caller. For events that represent external signals, whether a certain time is reached or something has occurred, there may not be a Java execution context, or at least that context is of necessity limited and often needs to have a very short duration; dispatching an unlimited number of handlers is not acceptable. They require an additional execution context for releasing handlers.

In order to be able to distinguish between events that are caused to be fired by an outside mechanism from those that are fired from another thread, the former extend the `ActiveEvent` interface. Each class implementing `ActiveEvent` must provide its own `trigger` method for initiating the handler release by releasing another execution context. Since the `trigger` methods may vary in the number of their arguments depending on the type of event, they are not provided by the `ActiveEvent` class. Each `trigger` method must act as if it calls the `fire` method on its event and then terminates. Hence `trigger` has the same functional behavior as `fire`, but runs in this other execution context.

This extra execution context is exposed to the user as an `ActiveEventDispatcher`. There is an active event dispatcher for each kind of active event. The programmer does not need to write a dispatcher, but just creates the one of the corresponding type. The programmer does determine the priority and the affinity of a dispatcher, as well as determine the mapping between dispatchers and events.

Each event has a single dispatcher, but a dispatcher may serve many events. As with `fire`, the dispatcher releases handlers in reverse priority order, i.e., from highest to lowest. This enables the programmer to control the number of these execution contexts and still optimize how handlers are released.

The state space of an `ActiveEvent` is an extension of the state space for an `AsyncBaseEvent` depicted in Figure 8.2. `ActiveEvent` adds the notion of active and inactive on top of enabled and disabled, as depicted in Figure 8.3. Note that the enabled-disabled distinction only splits the active state. The inactive state is by definition disabled.

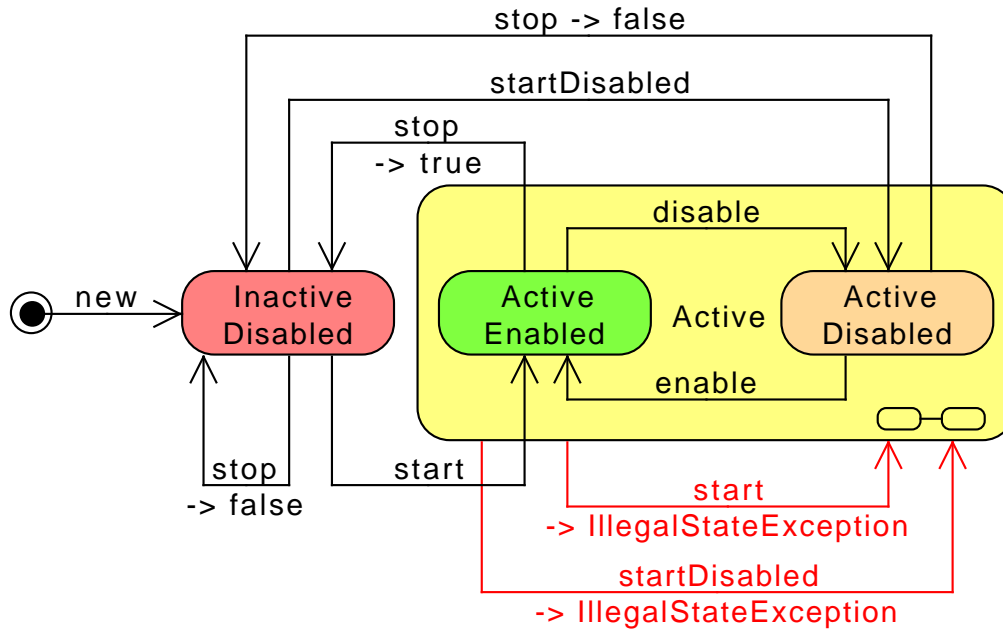
8.3.3 Asynchronous Transfer of Control

Asynchronously interrupting a schedulable consists of the following activities.

- **Generation** of an asynchronous interrupt exception — this is the event in the underlying system that makes the AIE available to the program.
- **Delivery** of the asynchronous interrupt exception to the target schedulable— this is the action that invokes the search for and execution of an appropriate handler.

Between the generation of an AIE and its delivery, the exception is held *pending*. The AIE remains pending (even after delivery) until it is **cleared** by the program logic using `clear()` or `doInterruptible()`.

Figure 8.3: States of an ActiveEvent



The following eight points define the semantics of ATC. Semantics that apply to particular classes, constructors, methods, and fields will be found in their detail sections, respectively.

1. An AIE is generated for a given schedulable when the `fire()` method is called on an AIE for which the schedulable object is executing within the `doInterruptible()` method or the `Schedulable.interrupt()` method is called; the latter is also effectively called when an AIE is generated by internal virtual machine mechanisms (such as an interrupted I/O operation) that are asynchronous to the execution of the program logic which is the target of the AIE. An AIE becomes pending upon generation and remains pending until explicitly cleared or replaced by another AIE.
2. The `Schedulable.interrupt()` method throws the generic AIE at the target realtime thread and has the behaviors defined for `Thread.interrupt()`. This is the only interaction between the ATC mechanism and the conventional `interrupt()` mechanism.
3. An AIE is delivered to a schedulable when it is executing in a method declared

to throw AIE, except in an ATC-deferred section as defined below.

- (a) The generation of an AIE through the `fire()` mechanism behaves as if it set an asynchronously-interrupted status in the schedulable.
 - i. When the schedulable is blocked within an interruptible blocking method or invokes an interruptible blocking method when this asynchronously-interrupted status is set, the invocation immediately completes by throwing the pending AIE and clearing the asynchronously-interrupted status.
 - ii. When a pending AIE is explicitly cleared then the asynchronously-interrupted status is also cleared.
- (b) Methods which block through mechanisms other than the interruptible blocking methods, (for example, blocking methods in `java.io.*`) must be prevented from blocking indefinitely when invoked from a method with `AsynchronouslyInterruptedException` in its `throws` clause. When an AIE is generated and the target schedulable's control is blocked inside one of these methods invoked from an AI-method, the implementation may either unblock the blocked call, raise an `InterruptedException` on behalf of the call, or allow the call to complete normally if the implementation determines that the call would eventually unblock.
- (c) When an AI-method is attempting to acquire an object lock when an associated AIE is generated, the attempt to acquire the lock is abandoned.
- (d) When control is in the lexical scope of an ATC-deferred section when an AIE (targeted at the executing schedulable) is generated, the AIE is not delivered until the first subsequent attempt to transfer control to code that is not ATC deferred. At that point, control is transferred to the `catch` or `finally` clause of the nearest dynamically-enclosing `try` statement that *i)* has a handler for the generated AIE (that is a handler naming the AIE's class or any of its superclasses, or a `finally` clause) and *ii)* is in an ATC-deferred section. Intervening handlers and `finally` clauses that are not in ATC-deferred sections are not executed, but object locks are released.

See section 11.3 of *The Java Language Specification* second edition for an explanation of the terms, *dynamically enclosing* and *handler*. The RTSJ uses those JLS definitions unaltered. Note that if synchronized code is abandoned as a result of this control transfer, the associated locks are released.

- 4. Constructors are allowed to include `AsynchronouslyInterruptedException` in their `throws` clause and if they do will be asynchronously interruptible under the same conditions as AI methods.
- 5. Native methods that include `AsynchronouslyInterruptedException` in their

throws clause have implementation-specific behavior.

6. An implementation must deliver the transfer of control in a schedulable that is subject to asynchronous interruption (in an AI-method but not in a synchronized block) within a bounded execution time of that schedulable. This worst-case response interval must be documented for some reference architecture.
7. Instances of the **Timed** class have a logically associated timer. When the timer fires, the schedulable executing the instance's **doInterruptible** method must have the AIE generated within a bounded execution time of the schedulable. This worst-case response interval must be documented for some reference architecture.
8. An AIE only has the semantics defined here when it originates with the **AsynchronouslyInterruptedException.fire()** method, the **Schedulable.interrupt()** method or from within the realtime VM. If an AIE is thrown from program logic using the Java throw statement, it uses the same semantics as throwing any other instance of a subclass of **Exception**, it is processed as a normal exception, and has no affect on the pending state of any AIE, and no affect on the firing of the AIE concerned.

8.3.3.1 Summary of ATC Operation

The RTSJ's approach to ATC is designed to follow the above principles. It is based on exceptions and is an extension of the current Java language rules for `java.lang.Thread.interrupt()`. In summary, ATC works as follows.

When **so** is an instance of a schedulable and the **interrupt()** method is called on the realtime thread associated with that object (in this context, the associated realtime thread of an AEH is the realtime thread returned by a call of the **RealtimeThread.currentRealtimeThread()** method by that AEH) then:

1. When control is in an ATC-deferred section, then the AIE remains in a pending state.
2. When control is not in an ATC-deferred section, then control is transferred to the **catch** or **finally** clause of the nearest dynamically-enclosing a **try** statement that has a handler for the generated AIE's (that is a handler naming the AIE's class or any of its superclasses, or a **finally** clause) and which is in an ATC-deferred section. Intervening handlers and **finally** clauses that are not in ATC-deferred sections are not executed, but objects locks are released. See section 11.3 of *The Java Language Specification* second edition for an explanation of the terms, *dynamically enclosing* and *handles*. The RTSJ uses those definitions unaltered.
3. When control is in an interruptible blocking method, the schedulable object is awakened and the generated AIE (which is a subclass of **InterruptedEx-**

- ception) is thrown with regular Java semantics (the AIE is still marked as pending). Then ATC follows option 1 or 2 as appropriate.
4. When control is in an ATC-deferred section, execution continues normally until the first attempt to return to an AI method or invoke an AI method or exit a synchronized block within an AI method. Then ATC follows option 1 or 2 as appropriate.
 5. When control is transferred from an ATC-deferred section to an AI method through the action of propagating an exception while an AIE is pending, when the transition to the AI-method occurs, the thrown exception is discarded and replaced by the AIE.

An AIE may be generated while another AIE is pending. Because AI code blocks are nested by method invocation (a stack-based nesting) there is a natural precedence among active instances of AIE. Let AIE_0 be the AIE raised when the `RealtimeThread.interrupt()` method is invoked and AIE_i ($i = 1, \dots, n$, for n unique instances of AIE) be the AIE generated when `AIE.fire()` is invoked. In the following, the phrase “a frame deeper on the stack than this frame” refers to a method nearer to the current stack frame. The phrase “a frame shallower on the stack than this frame” refers to a method further from the current stack frame.

- When the current AIE is an AIE_0 and the new AIE is an AIE_x associated with any frame on the stack, the new AIE (AIE_x) is discarded.
- When the current AIE is an AIE_x and the new AIE is an AIE_0 , the current AIE (AIE_x) is replaced by the new AIE (AIE_0).
- When the current AIE is an AIE_x and the new AIE is an AIE_y from a frame deeper on the stack, the new AIE (AIE_y) is discarded.
- When the current AIE is an AIE_x and the new AIE is an AIE_y from a frame shallower on the stack, the current AIE (AIE_x) is replaced by the new AIE (AIE_y).
- When the current AIE is an AIE_0 and the new AIE is an AIE_0 , or when the current AIE is an AIE_x and the new AIE is an AIE_x , the new AIE is discarded.

When `clear()` is called on a pending AIE or that AIE is superseded by another, the first AIE’s pending state is cleared. If the `happened()` method is called on a nonpending AIE the result depends on the value of the `propagate` parameter, as indicated in the “No Match” column of the table below. Clearing a nonpending AIE

(with the `clear()` method) has no effect.

propagate	Match	No Match
true	clear the pending AIE, return true	the AIE remains pending, propagate
false	clear the pending AIE, return true	the AIE remains pending, return false

8.4 Package javax.realtime

8.4.1 Interfaces

8.4.1.1 ActiveEvent

Interfaces

Releasable

This is the interface for defining the active event system. Classes implementing **ActiveEvent** are used to connect events that take place outside the Java virtual machine to RTSJ activities.

When an event takes place outside the Java virtual machine, some event-specific code within the Java virtual machine executes. That code notifies the **ActiveEvent** infrastructure of this event by calling a **trigger** method in the event.

8.4.1.1.1 Methods

isActive

Signature

```
public  
boolean isActive()
```

Determine the activation state of this event, i.e., it has been started but not yet stopped again.

Returns

true when active, **false** otherwise.

isRunning

Signature

```
public  
boolean isRunning()
```

Determine the running state of this event, i.e., it is both active and enabled.

Returns

true when active and enabled, **false** otherwise.

start

Signature

```
public  
void start()  
throws IllegalStateException
```

Start this active event.

Throws

`IllegalStateException` when this event has already been started.

start(boolean)

Signature

```
public  
void start(boolean disabled)  
throws IllegalStateException
```

Start this active event.

Parameters

`disabled` true for starting in a disabled state.

Throws

`IllegalStateException` when this event has already been started.

stop

Signature

```
public  
boolean stop()  
throws IllegalStateException
```

Stop this active event.

Throws

`IllegalStateException` when this event is not running.

Returns

the previous enabled state.

enable

Signature

```
public
void enable()
```

Change the state of the event so that associated handlers are release on fire. Each subclass provides a means of dispatching its handlers when requested. This method enables that request mechanism.

disable

Signature

```
public
void disable()
```

Change the state of the event so that associated handlers are skipped on fire. Each subclass provides a fire method as means of dispatching its handlers when requested. This method disables that request mechanism.

8.4.1.2 AsyncTimable

Interfaces

Timable

A common type for [Timer](#)¹ and [RealtimeThread](#)² to indicate that they can be associated with a [Clock](#)³ and be suspended waiting for time events based on that clock.

8.4.1.2.1 Methods

fire

Signature

```
public
void fire()
```

¹Section [10.4.2.5](#)

²Section [5.3.2.2](#)

³Section [10.4.2.1](#)

Inform the dispatcher associated with this `Timable` that a time event has occurred.

8.4.1.3 `BoundAsyncBaseEventHandler`

Interfaces

`BoundSchedulable`

An marker interface for all schedulables that are bound to a single thread of control. It is required to enable references to all bound handlers.

8.4.1.4 `InterruptedException`

`InterruptedException` is an interface implemented by classes that will be used as arguments on the method `doInterruptedException()` of `AsynchronouslyInterruptedException`⁴ and its subclasses. `doInterruptedException()` invokes the implementation of the method in this interface.

8.4.1.4.1 `Methods`

`run(AsynchronouslyInterruptedException)`

Signature

```
public
void run(AsynchronouslyInterruptedException exception)
throws AsynchronouslyInterruptedException
```

The main piece of code that is executed when an implementation is given to `doInterruptedException()`. When a class is created that implements this interface (for example through an anonymous inner class) it must include the `throws` clause to make the method interruptible.

Parameters

⁴Section [8.4.2.1](#)

exception The AIE object whose `doInterruptible` method is calling the `run` method. Used to invoke methods on [AsynchronouslyInterruptedException](#)⁵ from within the `run()` method.

interruptAction(AsynchronouslyInterruptedException)

Signature

```
public  
void interruptAction(AsynchronouslyInterruptedException exception)
```

This method is called by the system when the `run()` method is interrupted. Using this, the program logic can determine when the `run()` method completed normally or had its control asynchronously transferred to its caller.

Parameters

exception The currently pending AIE. Used to invoke methods on [AsynchronouslyInterruptedException](#)⁶ from within the `interruptAction()` method.

8.4.1.5 Releasable

8.4.1.5.1 Methods

getDispatcher

Signature

```
public  
D extends javax.realtime.ActiveEventDispatcher<D, T> getDispatcher()
```

⁵Section [8.4.2.1](#)

⁶Section [8.4.2.1](#)

8.4.2 Exceptions

8.4.2.1 AsynchronouslyInterruptedException

Inheritance

```

java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.InterruptedException
        javax.realtime.AsynchronouslyInterruptedException

```

A special exception that is thrown in response to an attempt to asynchronously transfer the locus of control of a schedulable.

A schedulable that is executing a method or constructor, which is declared with an **AsynchronouslyInterruptedException**⁷ in its **throws** clause, can be asynchronously interrupted except when it is executing in the lexical scope of a synchronized statement within that method/constructor. As soon as the schedulable object leaves the lexical scope of the method by calling another method/constructor it may be asynchronously interrupted when the called method/constructor is asynchronously interruptible. (See this chapter's introduction section for the detailed semantics).

The asynchronous interrupt is generated for a schedulable, **t**, when the **t.interrupt()** method is called or the **fire**⁸ method is called of an AIE for which **t** has a **doInterruptible** method call in progress.

The interrupt is also generated for an AEH (or BAEH), **h**, when the **fire**⁹ method is called of an AIE for which **h** has a **doInterruptible** method call in progress.

When an asynchronous interrupt is generated when the target schedulable is executing within an ATC-deferred section, the asynchronous interrupt becomes pending. A pending asynchronous interrupt is delivered when the target schedulable next attempts to enter asynchronously interruptible code.

Asynchronous transfers of control (ATCs) are intended to allow long-running computations to be terminated without the overhead or latency of polling with **name**.

When **Schedulable.interrupt**¹⁰, or **AsynchronouslyInterruptedException.fire()** is called, the **AsynchronouslyInterruptedException** is compared against any currently pending **AsynchronouslyInterruptedException** on the schedulable. When there is none, or when the depth of the **AsynchronouslyInterruptedException**

⁷Section 8.4.2.1

⁸Section 8.4.2.1.2

⁹Section 8.4.2.1.2

¹⁰Section 6.4.1.3.1

is less than the currently pending `AsynchronouslyInterruptedException`; (i.e., it is targeted at a less deeply nested method call), the new `AsynchronouslyInterruptedException` becomes the currently pending `AsynchronouslyInterruptedException` and the previously pending `AsynchronouslyInterruptedException` is discarded. Otherwise, the new `AsynchronouslyInterruptedException` is discarded.

When an `AsynchronouslyInterruptedException` is caught, the catch clause may invoke the `clear()` method on the `AsynchronouslyInterruptedException` in which it is interested to see if the exception matches the pending `AsynchronouslyInterruptedException`. When so, the pending `AsynchronouslyInterruptedException` is cleared for the schedulable and `clear` returns true. Otherwise, the current AIE remains pending and `clear` returns false.

`RealtimeThread.interrupt()` generates a system-wide generic `AsynchronouslyInterruptedException` which will always propagate outward through interruptible methods until the generic `AsynchronouslyInterruptedException` is identified and handled. The pending state of the generic AIE is per-schedulable object.

Other sources (e.g., `AsynchronouslyInterruptedException.fire()` and [Timed¹¹](#)) will generate specific instances of `AsynchronouslyInterruptedException` which applications can identify and thus limit propagation.

8.4.2.1.1 Constructors

AsynchronouslyInterruptedException

Signature

```
public  
    AsynchronouslyInterruptedException()
```

Create an instance of `AsynchronouslyInterruptedException`.

8.4.2.1.2 Methods

`getGeneric`

¹¹Section [8.4.2.2](#)

Signature

```
public static
    javax.realtime.AsynchronouslyInterruptedException getGeneric()
```

Gets the singleton system generic `AsynchronouslyInterruptedException` that is generated when `Schedulable.interrupt()`¹² is invoked.

Throws

`IllegalThreadStateException` when the current thread is a Java thread.

Returns

The generic `AsynchronouslyInterruptedException`.

enable*Signature*

```
public
    boolean enable()
```

Enable the throwing of this exception. This method is valid only when the caller has a call to `doInterruptible()` in progress. When invoked when no call to `doInterruptible()` is in progress, `enable` returns false and does nothing.

Returns

True when `this` was disabled before the method was called and the call was invoked whilst the associated `doInterruptible()` is in progress. False: otherwise.

disable*Signature*

```
public synchronized
    boolean disable()
```

Disable the throwing of this exception. When the `fire`¹³ method is called on `this` AIE whilst it is disabled, the fire is held pending and delivered as soon as the AIE is enabled and the interruptible code is within an AI-method. When an AIE is pending when the associated disable method is called, the AIE remains pending, and is delivered as soon as the AIE is enabled and the interruptible code is within an AI-method.

¹²Section 6.4.1.3.1

¹³Section 8.4.2.1.2

This method is valid only when the caller has a call to `doInterruptible()` in progress. If invoked when no call to `doInterruptible()` is in progress, `disable` returns false and does nothing.

Note: disabling the genericAIE associated with a schedulable only affects the firing of that AIE. When the genericAIE is generated by the `Schedulable.interrupt()`¹⁴ mechanism, the AIE is delivered (unless the `Interruptible` code is in an AI-deferred region, in which case it is marked as pending and handled in the usual way).

Returns

True when `this` was enabled before the method was called and the call was invoked with the associated `doInterruptible()` in progress. False: otherwise.

isEnabled

Signature

```
public  
boolean isEnabled()
```

Query the enabled status of this exception.

This method is valid only when the caller has a call to `doInterruptible()` in progress. If invoked when no call to `doInterruptible()` is in progress, `enable` returns false and does nothing.

Returns

True when this is enabled and the method call was invoked in the context of the associated `doInterruptible()`. False otherwise.

fire

Signature

```
public  
boolean fire()
```

Generate this exception when its `doInterruptible()` has been invoked and not completed. When `this` is the only outstanding AIE on the schedulable object that invoked this AIE's `doInterruptible(Interruptible)`¹⁵ method, this AIE becomes that schedulable's current AIE. Otherwise, it only becomes the current AIE when it is at a less deep level of nesting compared with the current outstanding AIE.

Returns

¹⁴Section 6.4.1.3.1

¹⁵Section 8.4.2.1.2

True when **this** is not disabled and it has an invocation of a **doInterruptible()** in progress and there is no outstanding fire request. False otherwise.

doInterruptible(Interruptible)

Signature

```
public  
boolean doInterruptible(Interruptible logic)
```

Executes the **run()** method of the given **Interruptible**¹⁶. This method may be on the stack in exactly one **Schedulable**¹⁷ object. An attempt to invoke this method in a schedulable while it is on the stack of another or the same schedulable will cause an immediate return with a value of false.

The **run** method of given **Interruptible** is always entered with the exception in the enabled state, but that state can be modified with **enable()**¹⁸ and **disable()**¹⁹ and the state can be observed with **isEnabled()**²⁰.

This AIE is cleared on return from **doInterruptible()**.

Parameters

logic An instance of an **Interruptible**²¹ whose **run()** method will be called.

Throws

IllegalThreadStateException when called from a Java thread.

IllegalArgumentException when **logic** is null.

Returns

True when the method call completed normally. False when another call to **doInterruptible** has not completed.

clear

Signature

```
public  
boolean clear()
```

Atomically see if **this** is pending on the currently executing schedulable, and when so, make it non-pending.

¹⁶Section 8.4.1.4

¹⁷Section 6.4.1.3

¹⁸Section 8.4.2.1.2

¹⁹Section 8.4.2.1.2

²⁰Section 8.4.2.1.2

²¹Section 8.4.1.4

Throws

`IllegalThreadStateException` when called from a Java thread.

Returns

True when `this` was pending. False when `this` was not pending.

8.4.2.2 Timed**Inheritance**

```

java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.InterruptedException
        javax.realtime.AsynchronouslyInterruptedException
          javax.realtime.Timed

```

Create a scope in a [Schedulable](#)²² object which will be asynchronously interrupted at the expiration of a timer. This timer will begin measuring time at some point between the time `doInterruptible()` is invoked and the time the `run()` method of the `Interruptible` object is invoked. Each call of `doInterruptible()` on an instance of `Timed` will restart the timer for the amount of time given in the constructor or the most recent invocation of `resetTime()`. The timer is cancelled when it has not expired before the `doInterruptible()` method has finished.

All memory use of an instance of `Timed` occurs during construction or the first invocation of `doInterruptible()`. Subsequent invocations of `doInterruptible()` do not allocate memory.

When the timer fires, the resulting AIE will be generated for the schedulable within a bounded execution time of the targeted schedulable.

Typical usage: `new Timed(T).doInterruptible(interruptible);`

8.4.2.2.1 Constructors**Timed(HighResolutionTime)***Signature*

```

public
Timed(javax.realtime.HighResolutionTime<?> time)

```

²²Section [6.4.1.3](#)

throws `IllegalArgumentException`,
`UnsupportedOperationException`

Create an instance of `Timed` with a timer set to `time`. When the `time` is in the past the [AsynchronouslyInterruptedException²³](#) mechanism is activated immediately after or when the `doInterruptible()` method is called.

Parameters

`time` When `time` is a [RelativeTime²⁴](#) value, it is the interval of time between the invocation of `doInterruptible()` and when the schedulable is asynchronously interrupted. When `time` is an [AbsoluteTime²⁵](#) value, the timer asynchronously interrupts at this time (assuming the timer has not been cancelled).

Throws

`IllegalArgumentException` when `time` is null.

`UnsupportedOperationException` when `time` is not based on a [Clock²⁶](#).

8.4.2.2.2 Methods

`doInterruptible(Interruptible)`

Signature

```
public  
boolean doInterruptible(Interruptible logic)
```

Execute a time-out method. Starts the timer and executes the `run()` method of the given [Interruptible²⁷](#) object.

Parameters

`logic`

Throws

`IllegalArgumentException`

`IllegalThreadStateException`

Returns

²³Section [8.4.2.1](#)

²⁴Section [9.4.1.3](#)

²⁵Section [9.4.1.1](#)

²⁶Section [10.4.2.1](#)

²⁷Section [8.4.1.4](#)

resetTime(HighResolutionTime)

Signature

```
public  
void resetTime(javax.realtime.HighResolutionTime<?> time)
```

To set the time-out for the next invocation of `doInterruptible()`.

Parameters

time This can be an absolute time or a relative time. When `null` or not based on a `Clock`²⁸, the time-out is not changed.

restart(HighResolutionTime)

Signature

```
public  
void restart(javax.realtime.HighResolutionTime<?> time)
```

Reset the timeout. When this `Timed`²⁹ instance is executing, adjust the timeout to `time` and restart the timer. When the instance is not executing, adjust the timeout for the next invocation.

Parameters

time The new timeout.

Throws

`IllegalArgumentException` when `time` is `null` or a relative time less than zero.

`UnsupportedOperationException` when `time` is not based on a `Clock`³⁰

8.4.3 Classes

8.4.3.1 ActiveEventDispatcher

Inheritance

```
java.lang.Object  
    javax.realtime.ActiveEventDispatcher
```

Interfaces

²⁸Section 10.4.2.1

²⁹Section 8.4.2.2

³⁰Section 10.4.2.1

RealtimeExecutionContext

Provides a means of dispatching a set of [ActiveEvent](#)³¹s. It acts as if it contains a `RealtimeThread` to perform this task. The priority of this thread can be specified when a dispatcher object is created. The default dispatcher runs at the highest realtime priority.

Application code should not extend this class.

8.4.3.1.1 Constructors

ActiveEventDispatcher(SchedulingParameters)

Signature

```
protected  
ActiveEventDispatcher(SchedulingParameters schedule)
```

Create a new dispatcher.

Parameters

`schedule` provide scheduling information to the new object.

8.4.3.1.2 Methods

getSchedulingParameters

Signature

```
public  
javax.realtime.SchedulingParameters getSchedulingParameters()
```

register(T)

Signature

³¹Section [8.4.1.1](#)

```
public abstract
void register(T event)
throws RegistrationException,
        IllegalStateException,
        IllegalArgumentException
```

Register an active event with this dispatcher.

Parameters

`event` to register

Throws

`RegistrationException` when `event` is already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `event` is not stopped.

unregister(T)

Signature

```
public abstract
void unregister(T event)
throws DeregistrationException,
        IllegalStateException,
        IllegalArgumentException
```

Deregister an active event form this dispatcher.

Parameters

`event` to deregister

Throws

`DeregistrationException` when `event` is already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `event` is not stopped.

destroy

Signature

```
public abstract
void destroy()
throws IllegalStateException
```

Makes the dispatcher unusable.

Throws

`IllegalStateException` when called on a dispatcher that has one or more registered objects.

8.4.3.2 AsyncBaseEvent

Inheritance

`java.lang.Object`
`javax.realtime.AsyncBaseEvent`

This is the base class for all asynchronous events, where asynchronous is in regards to running code, not external time. This class unifies the original `AsyncEvent`³² with `AsyncLongEvent`³³ and `AsyncObjectEvent`³⁴.

8.4.3.2.1 Methods

isRunning

Signature

```
public  
boolean isRunning()
```

Determine the firing state (releasing or skipping) of this event, i.e., whether it is enabled or disabled.

Returns

`true` when releasing, `false` when skipping.

handledBy(AsyncBaseEventHandler)

Signature

```
public  
boolean handledBy(AsyncBaseEventHandler handler)
```

³²Section 8.4.3.4

³³Section 8.4.3.6

³⁴Section 8.4.3.8

Test to see if the handler given as the parameter is associated with **this**.

Parameters

handler The handler to be tested to determine if it is associated with **this**.

Returns

True when the parameter is associated with **this**. False when **handler** is **null** or the parameters is not associated with **this**.

enable

Signature

```
public  
void enable()
```

Change the state of the event so that associated handlers are release on fire. Each subclass provides a means of dispatching its handlers when requested. This method enables that request mechanism.

disable

Signature

```
public  
void disable()
```

Change the state of the event so that associated handlers are skipped on fire. Each subclass provides a fire method as means of dispatching its handlers when requested. This method disables that request mechanism.

addHandler(AsyncBaseEventHandler)

Signature

```
public  
void addHandler(AsyncBaseEventHandler handler)
```

Add a handler to the set of handlers associated with this event. An instance of **AsyncBaseEvent** may have more than one associated handler. However, adding a handler to an event has no effect when the handler is already attached to the event.

The execution of this method is atomic with respect to the execution of the **fire()** method.

Note, there is an implicit reference to the handler stored in **this**. The assignment must be valid under any applicable memory assignment rules.

Parameters

handler The new handler to add to the list of handlers already associated with this. When **handler** is already associated with the event, the call has no effect.

Throws

`IllegalArgumentException` when **handler** is `null` or the handler has `PeriodicParameters`³⁵. Only the subclass `PeriodicTimer`³⁶ is allowed to have handlers with `PeriodicParameters`³⁷.

`IllegalAssignmentError` when this `AsyncBaseEvent` cannot hold a reference to **handler**.

`IllegalStateException` if the configured `Scheduler` and `SchedulingParameters` for **handler** are not compatible with one another.

setHandler(AsyncBaseEventHandler)*Signature*

```
public
void setHandler(AsyncBaseEventHandler handler)
```

Associate a new handler with this event and remove all existing handlers. The execution of this method is atomic with respect to the execution of the `fire()` method.

Parameters

handler The instance of `AsyncBaseEventHandler`³⁸ to be associated with this. When **handler** is `null` then no handler will be associated with this, i.e., behave effectively as if `setHandler(null)` invokes `removeHandler(AsyncBaseEventHandler)`³⁹ for each associated handler.

Throws

`IllegalArgumentException` when **handler** has `PeriodicParameters`⁴⁰. Only the subclass `PeriodicTimer`⁴¹ is allowed to have handlers with `PeriodicParameters`⁴².

³⁵Section 6.4.2.5

³⁶Section 10.4.2.3

³⁷Section 6.4.2.5

³⁸Section 8.4.3.3

³⁹Section 8.4.3.2.1

⁴⁰Section 6.4.2.5

⁴¹Section 10.4.2.3

⁴²Section 6.4.2.5

`IllegalAssignmentError` when this `AsyncBaseEvent` cannot hold a reference to `handler`.

removeHandler(AsyncBaseEventHandler)

Signature

```
public  
void removeHandler(AsyncBaseEventHandler handler)
```

Remove a handler from the set associated with this event. The execution of this method is atomic with respect to the execution of the `fire()` method.

A removed handler continues to execute until its `fireCount` becomes zero and it completes.

When `handler` has a scoped non-default initial memory area and execution of this method causes `handler` to become non-fireable, this method shall not return until all related finalization has completed.

Parameters

handler The handler to be disassociated from **this**. When **null** nothing happens. When the **handler** is not already associated with **this** then nothing happens.

hasHandlers

Signature

```
public  
boolean hasHandlers()
```

Determine whether or not this event has any handlers

Returns

true when and only when at least one handler is associated with this event.

createReleaseParameters

Signature

```
public  
javax.realtime.ReleaseParameters createReleaseParameters()
```

Create a [ReleaseParameters](#)⁴³ object appropriate to the release characteristics of this event. The default is the most pessimistic: [AperiodicParameters](#)⁴⁴. This is typically called by code that is setting up a handler for this event that will fill in the parts of the release parameters for which it has values, e.g., cost. The returned [ReleaseParameters](#)⁴⁵ object is not bound to the event. Any changes in the event's release parameters are not reflected in previously returned objects.

When an event returns [PeriodicParameters](#)⁴⁶, there is no requirement for an implementation to check that the handler is released periodically.

Returns

A new [ReleaseParameters](#)⁴⁷ object.

8.4.3.3 AsyncBaseEventHandler

Inheritance

java.lang.Object
[javax.realtime.AsyncBaseEventHandler](#)

Interfaces

[Schedulable](#)

This is the base class for all asynchronous event handlers, where asynchronous is in regards to running code, not external time. This class unifies the original [AsyncEventHandler](#)⁴⁸ with [AsyncLongEventHandler](#)⁴⁹ and [AsyncObjectEventHandler](#)⁵⁰.

8.4.3.3.1 Methods

getCurrentConsumption(RelativeTime)

Signature

```
public static
javax.realtime.RelativeTime getCurrentConsumption(RelativeTime dest)
```

⁴³Section [6.4.2.9](#)

⁴⁴Section [6.4.2.2](#)

⁴⁵Section [6.4.2.9](#)

⁴⁶Section [6.4.2.5](#)

⁴⁷Section [6.4.2.9](#)

⁴⁸Section [8.4.3.5](#)

⁴⁹Section [8.4.3.7](#)

⁵⁰Section [8.4.3.9](#)

throws `IllegalStateException`

Determine the CPU consumption for this release. When `dest` is `null`, return the CPU consumption in an otherwise unused `RelativeTime`⁵¹ instance in the current execution context. Otherwise, when `dest` is not `null`, return the CPU consumption in `dest`

Parameters

`dest` when not `null` is the object in which to return the result.

Throws

`IllegalStateException` when the caller is not a `RealtimeThread`⁵².

Returns

the time consumed in the current release.

getCurrentConsumption

Signature

```
public static  
    javax.realtime.RelativeTime getCurrentConsumption()
```

Equivalent to `getCurrentConsumption(null)`.

Returns

the time consumed in the current release.

getPendingFireCount

Signature

```
protected  
    int getPendingFireCount()
```

This is an accessor method for `fireCount`. The `fireCount` field nominally holds the number of times associated instances of `AsyncEvent`⁵³ have occurred that have not had the method `handleAsyncEvent()` invoked. It is incremented and decremented by the implementation of the RTSJ. The application logic may manipulate the value in this field for application-specific reasons.

Returns

The value held by `fireCount`.

⁵¹Section 9.4.1.3

⁵²Section 5.3.2.2

⁵³Section 8.4.3.4

getAndClearPendingFireCount

Signature

```
protected
int getAndClearPendingFireCount()
```

This is an accessor method for **fireCount**. This method atomically sets the value of **fireCount** to zero and returns the value from before it was set to zero. This may be used by handlers for which the logic can accommodate multiple releases in a single execution.

The general form for using this is

```
public void handleAsyncEvent()
{
    int numberOfReleases = getAndClearPendingFireCount();
    <handle the events>
}
```

The effect of a call to **getAndClearPendingFireCount** on the scheduling of this AEH depends on the semantics of the scheduler controlling this AEH.

Returns

The value held by **fireCount** prior to setting the value to zero.

getAndDecrementPendingFireCount

Signature

```
protected
int getAndDecrementPendingFireCount()
```

This is an accessor method for **fireCount**. This method atomically decrements, by one, the value of **fireCount** (when it is greater than zero) and returns the value from before the decrement. This method can be used in the **handleAsyncEvent()** method to handle multiple releases:

```
public void handleAsyncEvent()
{
    <setup>
    do
    {
        <handle the event>
    }
    while(getAndDecrementPendingFireCount() > 0);
}
```

This construction is necessary only in the case where a handler wishes to avoid the setup costs since the framework guarantees that `handleAsyncEvent()` will be invoked whenever the `fireCount` is greater than zero. The effect of a call to `getAndDecrementPendingFireCount` on the scheduling of this AEH depends on the semantics of the scheduler controlling this AEH.

Returns

The value held by `fireCount` prior to decrementing it by one.

getMemoryArea

Signature

```
public  
javax.realtime.MemoryArea getMemoryArea()
```

This is an accessor method for the initial instance of `MemoryArea`⁵⁴ associated with `this`.

Returns

The instance of `MemoryArea`⁵⁵ which was passed as the `area` parameter when `this` was created (or the default value when `area` was allowed to default. To determine the current status of the memory area stack associated with `this`, use the static methods defined in the `RealtimeThread`⁵⁶ class. That is `RealtimeThread.getCurrentMemoryArea`⁵⁷, `RealtimeThread.getInitialMemoryAreaIndex`⁵⁸, `RealtimeThread.getMemoryAreaStackDepth`⁵⁹.

getMemoryParameters

Signature

```
public  
javax.realtime.MemoryParameters getMemoryParameters()
```

Returns

⁵⁴Section 11.4.2.3

⁵⁵Section 11.4.2.3

⁵⁶Section 5.3.2.2

⁵⁷Section 5.3.2.2.2

⁵⁸Section 5.3.2.2.2

⁵⁹Section 5.3.2.2.2

getReleaseParameters

Signature

```
public  
    javax.realtime.ReleaseParameters getReleaseParameters()
```

Returns

getScheduler

Signature

```
public  
    javax.realtime.Scheduler getScheduler()
```

Returns

getSchedulingParameters

Signature

```
public  
    javax.realtime.SchedulingParameters getSchedulingParameters()
```

Returns

getSchedulingGroup

Signature

```
public  
    javax.realtime.SchedulingGroup getSchedulingGroup()
```

Returns

getConfigurationParameters

Signature

```
public  
javax.realtime.ConfigurationParameters getConfigurationParameters()
```

Returns

setMemoryParameters(MemoryParameters)

Signature

```
public  
void setMemoryParameters(MemoryParameters memory)
```

Parameters

memory

Throws

IllegalArgumentException
IllegalAssignmentError
IllegalThreadStateException

setReleaseParameters(ReleaseParameters)

Signature

```
public  
void setReleaseParameters(ReleaseParameters release)
```

Parameters

release

Throws

IllegalArgumentException
IllegalAssignmentError
IllegalThreadStateException

setScheduler(Scheduler)

Signature

```
public  
void setScheduler(Scheduler scheduler)
```

For an instance of `AsyncBaseEventHandler`, the `Schedulable` is *running* for the purpose of setting the scheduler if it is attached to an `AsyncEvent` (even if `AsyncBaseEvent.isRunning()`⁶⁰ would return `false` for that event).

Parameters

`scheduler`

Throws

`IllegalArgumentException`
`IllegalAssignmentError`
`SecurityException`
`IllegalThreadStateException`

setScheduler(Scheduler, SchedulingParameters, ReleaseParameters, MemoryParameters)

Signature

```
public  
void setScheduler(Scheduler scheduler,  
                  SchedulingParameters scheduling,  
                  ReleaseParameters release,  
                  MemoryParameters memoryParameters)
```

Parameters

`scheduler`
`scheduling`
`release`
`memoryParameters`

Throws

`IllegalArgumentException`
`IllegalAssignmentError`

⁶⁰Section 8.4.3.2.1

IllegalThreadStateException

SecurityException

setSchedulingParameters(SchedulingParameters)

Signature

```
public  
void setSchedulingParameters(SchedulingParameters scheduling)
```

Parameters

scheduling

Throws

IllegalArgumentException

IllegalAssignmentError

IllegalThreadStateException

setDaemon(boolean)

Signature

```
public final  
void setDaemon(boolean on)
```

Marks this event handler as either a daemon event handler or a user event handler. A realtime virtual machine exits when the only schedulables and threads running are all daemon. This method must be called before the event handler is attached to any event. Once attached, it cannot be changed.

Parameters

on When true, marks this event handler as a daemon handler.

Throws

IllegalThreadStateException when this event handler is attached to an AE.

SecurityException when the current schedulable cannot modify this event handler.

isDaemon

Signature

```
public final
boolean isDaemon()
```

Tests if this event handler is a daemon handler.

Returns

True when this event handler is a daemon handler; false otherwise.

getDispatcher

Signature

```
public
javax.realtime.TimeDispatcher getDispatcher()
```

See Section `AsyncTimable.getDispatcher()`

getMinConsumption(RelativeTime)

Signature

```
public
javax.realtime.RelativeTime getMinConsumption(RelativeTime dest)
```

Determine the minimum CPU consumption of all completed releases. When `dest` is `null`, return the CPU consumption in an otherwise unused [RelativeTime](#)⁶¹ instance in the current execution context. Otherwise, when `dest` is not `null`, return the CPU consumption in `dest`

Parameters

`dest` when not `null` is the object in which to return the result.

Returns

the minimum time consumed in any release.

getMinConsumption

Signature

```
public
javax.realtime.RelativeTime getMinConsumption()
```

Same as [getMinConsumption\(RelativeTime\)](#)⁶² with a `null` argument.

⁶¹Section [9.4.1.3](#)

⁶²Section [8.4.3.3.1](#)

Returns

the minimum time consumed in any release.

getMaxConsumption(RelativeTime)*Signature*

```
public  
javax.realtime.RelativeTime getMaxConsumption(RelativeTime dest)
```

Determine the maximum CPU consumption of all completed releases. When `dest` is `null`, return the CPU consumption in an otherwise unused [RelativeTime](#)⁶³ instance in the current execution context. Otherwise, when `dest` is not `null`, return the CPU consumption in `dest`

Parameters

`dest` when not `null` is the object in which to return the result.

Returns

the maximum time consumed in any release.

getMaxConsumption*Signature*

```
public  
javax.realtime.RelativeTime getMaxConsumption()
```

Same as [getMaxConsumption\(RelativeTime\)](#)⁶⁴ with a `null` argument.

Returns

the maximum time consumed in any release.

mayUseHeap*Signature*

```
public  
boolean mayUseHeap()
```

Determine whether or not this `schedulable` may use the heap.

Returns

⁶³Section [9.4.1.3](#)

⁶⁴Section [8.4.3.3.1](#)

`true` only when this `Schedulable` may allocate on the heap and may enter the Heap.

interrupt

Signature

```
public  
void interrupt()
```

Generates the generic `AsynchronouslyInterruptedException`⁶⁵ and targets it at this, and sets the interrupted state to pending. As with `Thread.interrupt()`, blocking operations that are interruptible are interrupted.

isRousable

Signature

```
public  
boolean isRousable()
```

Determine if it is possible for an interruptible to prematurely release the handler.

Returns

`true` when it is possible, otherwise it is not.

setRousable(boolean)

Signature

```
public  
void setRousable(boolean value)
```

Set the state for whether a interrupt can prematurely release this handler or not.

Parameters

`value` is the new value of the wake by interrupt state.

awaken

Signature

⁶⁵Section 8.4.2.1

```
public final  
void awaken()
```

Indicate that a sleep has ended.
[See Section `Schedulable.awaken\(\)`](#)

8.4.3.4 AsyncEvent

Inheritance

```
java.lang.Object  
  javax.realtime.AsyncBaseEvent  
    javax.realtime.AsyncEvent
```

An asynchronous event can have a set of handlers associated with it, and when the event occurs, the `fireCount` of each handler is incremented, and the handlers are released (see [AsyncEventHandler⁶⁶](#)).

8.4.3.4.1 Constructors

AsyncEvent

Signature

```
public  
AsyncEvent()
```

Create a new `AsyncEvent` object.

8.4.3.4.2 Methods

fire

Signature

⁶⁶Section [8.4.3.5](#)

```
public
void fire()
```

When enabled, release the asynchronous events associated with this instance of `AsyncEvent`. When no handlers are attached or this object is disabled the method does nothing, i.e., it skips the release.

- When the instance of `AsyncEvent` has more than one instance of `AsyncEventHandler` with release parameters object of type `AperiodicParameters` attached and the execution of `AsyncEvent.fire()` introduces the requirement to throw at least one type of exception, then all instances of `AsyncEventHandler` not affected by the exception are handled normally
- When the instance of `AsyncEvent` has more than one instance of `AsyncEventHandler` with release parameters object of type `SporadicParameters` attached and the execution of `AsyncEvent.fire()` introduces the simultaneous requirement to throw more than one type of exception or error then `MITViolationException`⁶⁷ has precedence over `ArrivalTimeQueueOverflowException`⁶⁸.

Throws

`MITViolationException` Thrown under the base priority scheduler's semantics when there is a handler associated with this event that has its MIT violated by the call to fire (and it has set the minimum inter-arrival time violation behavior to `MITViolationExcept`). Only the handlers which do not have their MITs violated are released in this situation.

`ArrivalTimeQueueOverflowException` when the queue of arrival time information overflows. Only the handlers which do not cause this exception to be thrown are released in this situation.

8.4.3.5 AsyncEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncEventHandler
```

An asynchronous event handler encapsulates code that is released after an instance of `AsyncEvent`⁶⁹ to which it is attached occurs.

It is guaranteed that multiple releases of an event handler will be serialized. It is also guaranteed that (unless the handler explicitly chooses otherwise) for each release

⁶⁷Section 14.3.2.6

⁶⁸Section 14.3.2.1

⁶⁹Section 8.4.3.4

of the handler, there will be one execution of the `AsyncEventHandler.handleAsyncEvent()`⁷⁰ method. Control over the number of calls to `AsyncEventHandler.handleAsyncEvent()`⁷¹ is given by methods which manipulate a `fireCount`. These may be called by the application via sub-classing and overriding `AsyncEventHandler.handleAsyncEvent()`⁷².

Instances of `AsyncEventHandler` with a release parameter of type `SporadicParameters`⁷³ or `AperiodicParameters`⁷⁴ have a list of release times which correspond to the occurrence times of instances of `AsyncEvent`⁷⁵ to which they are attached. The minimum interarrival time specified in `SporadicParameters`⁷⁶ is enforced when a release time is added to the list. Unless the handler explicitly chooses otherwise, there will be one execution of the code in `AsyncEventHandler.handleAsyncEvent()`⁷⁷ for each entry in the list.

The deadline and the time each release event causes the AEH to become eligible for execution are properties of the scheduler that controls the AEH. For the base scheduler, the deadline for each release event is relative to its fire time, and the release takes place at fire time but execution eligibility may be deferred when the queue's MIT violation policy is `SAVE`.

Handlers may do almost anything a realtime thread can do. They may run for a long or short time, and they may block. (Note: blocked handlers may hold system resources.) A handler may not use the `RealtimeThread.waitForNextRelease`⁷⁸ method.

Normally, handlers are bound to an execution context dynamically when the instances of `AsyncEvent`⁷⁹s to which they are bound occur. This can introduce a (small) time penalty. For critical handlers that cannot afford the expense, and where this penalty is a problem, `BoundAsyncEventHandler`⁸⁰s can be used.

The scheduler for an asynchronous event handler is inherited from the thread/schedulable that created it. When it was created from a Java thread, the scheduler is the current default scheduler.

The semantics for memory areas that were defined for realtime threads apply in the same way to instances of `AsyncEventHandler`. They may inherit a scope stack when they are created, and the single parent rule applies to the use of memory scopes for instances of `AsyncEventHandler` just as it does in realtime threads.

⁷⁰Section 8.4.3.5.2

⁷¹Section 8.4.3.5.2

⁷²Section 8.4.3.5.2

⁷³Section 6.4.2.14

⁷⁴Section 6.4.2.2

⁷⁵Section 8.4.3.4

⁷⁶Section 6.4.2.14

⁷⁷Section 8.4.3.5.2

⁷⁸Section 5.3.2.2.2

⁷⁹Section 8.4.3.4

⁸⁰Section 8.4.3.10

8.4.3.5.1 Constructors

AsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)

Signature

```
public
AsyncEventHandler(SchedulingParameters scheduling,
                  ReleaseParameters release,
                  MemoryParameters memory,
                  MemoryArea area,
                  SchedulingGroup group,
                  ConfigurationParameters initial,
                  Runnable logic)
```

Create a handler with the given scheduling, release, memory, group, and configuration parameters to run the given logic.

Parameters

scheduling parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)⁸¹). When **scheduling** is **null** and the creator is an instance of [Schedulable](#)⁸², [SchedulingParameters](#)⁸³ is a clone of the creator's value created in the same memory area as **this**. When **scheduling** is **null** and the creator is a Java thread, the contents and type of the new [SchedulingParameters](#) object is governed by the associated scheduler.

release parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)⁸⁴). When **release** is **null** the new [AsyncEventHandler](#) will use a clone of the default [ReleaseParameters](#)⁸⁵ for the associated scheduler created in the memory area that contains the [AsyncEventHandler](#) object.

memory parameters for scheduling the new handler (and possibly other in-

⁸¹Section [6.4.1.3](#)

⁸²Section [6.4.1.3](#)

⁸³Section [6.4.2.13](#)

⁸⁴Section [6.4.1.3](#)

⁸⁵Section [6.4.2.9](#)

stances of [Schedulable](#)⁸⁶). When `memory` is `null`, the new `AsyncEventHandler` receives `null` value for its memory parameters, and the amount or rate of memory allocation for the new handler is unrestricted.

`area` the initial memory area of this handler.

`group` parameters for providing CPU cost management on a set of [Schedulable](#)⁸⁷s. When `null`, this will not be associated with any processing group.

`initial` parameters for reserving space for preallocated exceptions and change implementation specific per [Schedulable](#)⁸⁸ memory reservations, such as Java stack size, for the new handler (and possibly other instances of [Schedulable](#)⁸⁹. When `initial` is `null`, this `AsyncEventHandler` will reserve no space for preallocated exceptions and implementation-specific values will be set to their implementation-defined defaults.

`logic` The `Runnable` object whose `run()` method will serve as the logic for the new `AsyncEventHandler`. When `logic` is `null`, the `handleAsyncEvent()` method in the new object will serve as its logic.

AsyncEventHandler(SchedulingParameters, ReleaseParameters, Runnable)

Signature

```
public
AsyncEventHandler(SchedulingParameters scheduling,
                  ReleaseParameters release,
                  Runnable logic)
```

Calling this constructor is equivalent to calling [AsyncEventHandler\(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable\)](#)⁹⁰ with arguments (`scheduling`, `release`, `null`, `null`, `null`, `null`, `logic`).

AsyncEventHandler(SchedulingParameters, ReleaseParameters)

⁸⁶Section [6.4.1.3](#)

⁸⁷Section [6.4.1.3](#)

⁸⁸Section [6.4.1.3](#)

⁸⁹Section [6.4.1.3](#)

⁹⁰Section [8.4.3.5.1](#)

Signature

```
public  
AsyncEventHandler(SchedulingParameters scheduling,  
                  ReleaseParameters release)
```

Calling this constructor is equivalent to calling `AsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)`⁹¹ with arguments (scheduling, release, null, null, null, null, null).

AsyncEventHandler(Runnable)

Signature

```
public  
AsyncEventHandler(Runnable logic)
```

Calling this constructor is equivalent to calling `AsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)`⁹² with arguments (null, null, null, null, null, null, logic).

AsyncEventHandler

Signature

```
public  
AsyncEventHandler()
```

Create an instance of `AsyncEventHandler` with default values for all parameters. See Section `AsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)`

8.4.3.5.2 Methods

⁹¹Section 8.4.3.5.1

⁹²Section 8.4.3.5.1

handleAsyncEvent

Signature

```
public
void handleAsyncEvent()
```

This method holds the logic which is to be executed when any [AsyncEvent](#)⁹³ with which this handler is associated is fired. This method will be invoked repeatedly while `fireCount` is greater than zero.

The default implementation of this method invokes the `run` method of any non-null `logic` instance passed to the constructor of this handler.

This AEH acts as a source of "reference" for its initial memory area while it is released.

All throwables from (or propagated through) `handleAsyncEvent` are caught, a stack trace is printed and execution continues as if `handleAsyncEvent` had returned normally.

initialMemoryPinnable

Signature

```
public
boolean initialMemoryPinnable()
```

Test to see if the default memory area is a pinned scoped memory area.

Returns

true is the default memory area is a pinned scoped memory area.

run

Signature

```
public final
void run()
```

When used as part of the internal mechanism activated by firing an async event, this method's detailed semantics are defined by the scheduler associated with this handler. The general outline is:

```
enter initial memory area
while (fireCount > 0)
```

⁹³Section [8.4.3.4](#)

```

{
    [initiate release]
    fireCount--;
    try                { handleAsyncEvent();    }
    catch (Throwable th) { th.printStackTrace(); }
    [effect completion]
}
leave initial memory area

```

All throwables from (or propagated through) [handleAsyncEvent](#)⁹⁴ are caught, a stack trace is printed and execution continues as if `handleAsyncEvent` had returned normally.

When it is directly invoked, this method invokes [handleAsyncEvent](#)⁹⁵ repeatedly while the `fireCount` is greater than zero; e.g.,

```

while (getAndDecrementPendingFireCount() > 0)
{
    enter initial memory area
    handleAsyncEvent();
    leave initial memory area
}

```

however direct invocation of `run` is not recommended as it may interact with the normal release of this handler.

Applications cannot override this method and thus should use the `logic` parameter at construction, or override `handleAsyncEvent()` in subclasses with the logic of the handler.

8.4.3.6 AsyncLongEvent

Inheritance

```

java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncLongEvent

```

A new type of event that carries a long as a payload.

[See Section AsyncEvent](#)

⁹⁴Section [8.4.3.5.2](#)

⁹⁵Section [8.4.3.5.2](#)

8.4.3.6.1 Constructors

AsyncLongEvent

Signature

```
public  
AsyncLongEvent()
```

Create a new `AsyncLongEvent` object.

8.4.3.6.2 Methods

`fire(long)`

Signature

```
public  
void fire(long value)  
throws MITViolationException,  
        ArrivalTimeQueueOverflowException
```

When enabled, release the asynchronous events associated with this instance of `AsyncLongEvent` with the `long` passed by `fire(long)`⁹⁶. When no handlers are attached or this object is disabled the method does nothing, i.e., it skips the release.

- When the instance of `AsyncLongEvent` is associated with more than one instance of `AsyncLongEventHandler`⁹⁷ with release parameters object of type `AperiodicParameters`⁹⁸ and the execution of `fire(long)`⁹⁹ introduces the requirement to throw at least one type of exception, then all instances of `AsyncLongEventHandler`¹⁰⁰ not affected by the exception are handled normally.

⁹⁶Section 8.4.3.6.2

⁹⁷Section 8.4.3.7

⁹⁸Section 6.4.2.2

⁹⁹Section 8.4.3.6.2

¹⁰⁰Section 8.4.3.7

- When this instance of `AsyncLongEvent` is associated with more than one instance of `AsyncLongEventHandler`¹⁰¹ with release parameters object of type `SporadicParameters`¹⁰² and the execution of `fire(long)`¹⁰³ introduces the simultaneous requirement to throw more than one type of exception or error, then `MITViolationException`¹⁰⁴ has precedence over `ArrivalTimeQueueOverflowException`¹⁰⁵.

Parameters

`value` is the payload passed to the event.

Throws

`MITViolationException` Thrown under the base priority scheduler's semantics, when there is a handler associated with this event that has its MIT violated by the call to fire (and it has set the minimum inter-arrival time violation behavior to `MITViolationExcept`). Only the handlers which do not have their MITs violated are released in this situation.

`ArrivalTimeQueueOverflowException` when the queue of arrival time information overflows. Only the handlers which do not cause this exception to be thrown are released in this situation.

8.4.3.7 AsyncLongEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncLongEventHandler
```

A version of `AsyncBaseEventHandler`¹⁰⁶ that carries a `long` value as payload.

8.4.3.7.1 Constructors

AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)

¹⁰¹Section 8.4.3.7

¹⁰²Section 6.4.2.14

¹⁰³Section 8.4.3.6.2

¹⁰⁴Section 14.3.2.6

¹⁰⁵Section 14.3.2.1

¹⁰⁶Section 8.4.3.3

Signature

```
public
AsyncLongEventHandler(SchedulingParameters scheduling,
                      ReleaseParameters release,
                      MemoryParameters memory,
                      MemoryArea area,
                      SchedulingGroup group,
                      ConfigurationParameters sizing,
                      LongConsumer logic)
```

Create an asynchronous event handler that receives a `Long` payload with each fire.

Parameters

`scheduling` parameters for the new handler.
`release` parameters for the new handler.
`memory` parameters for the new handler.
`area` initial memory area for the new handler.
`group` parameters for the new handler.
`sizing` parameters for the new handler.
`logic` is the logic to run for each fire.

AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, LongConsumer)*Signature*

```
public
AsyncLongEventHandler(SchedulingParameters scheduling,
                      ReleaseParameters release,
                      LongConsumer logic)
```

Calling this constructor is equivalent to calling `AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)`¹⁰⁷ with arguments (scheduling, release, null, null, null, logic).

¹⁰⁷Section 8.4.3.7.1

AsyncLongEventHandler(SchedulingParameters, ReleaseParameters)

Signature

```
public
AsyncLongEventHandler(SchedulingParameters scheduling,
                     ReleaseParameters release)
```

Calling this constructor is equivalent to calling `AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)`¹⁰⁸ with arguments (scheduling, release, null, null, null, null, null).

AsyncLongEventHandler(LongConsumer)

Signature

```
public
AsyncLongEventHandler(LongConsumer logic)
```

Calling this constructor is equivalent to calling `AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)`¹⁰⁹ with arguments (null, null, null, null, null, null, logic).

AsyncLongEventHandler

Signature

```
public
AsyncLongEventHandler()
```

Create an instance of `AsyncLongEventHandler` with default values for all parameters.

See Section `AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongCon-`

¹⁰⁸Section 8.4.3.7.1

¹⁰⁹Section 8.4.3.7.1

sumer)

8.4.3.7.2 Methods

handleAsyncEvent(long)

Signature

```
public  
void handleAsyncEvent(long payload)
```

This method holds the logic which is to be executed when any [AsyncEvent](#)¹¹⁰ with which this handler is associated is fired. This method will be invoked repeatedly while `fireCount` is greater than zero.

This ALEH is a source of reference for its initial memory area while this ALEH is released.

All throwables from (or propagated through) `handleAsyncEvent` are caught, a stack trace is printed and execution continues as if `handleAsyncEvent` had returned normally.

Parameters

`payload` is the long value associated with a fire.

peekPending

Signature

```
public  
long peekPending()  
throws IllegalStateException
```

Throws

`IllegalStateException` when the fire count is zero.

Returns

The long value at the head of the queue of longs to be passed to [handleAsyncEvent\(long\)](#)¹¹¹.

¹¹⁰Section [8.4.3.4](#)

¹¹¹Section [8.4.3.7.2](#)

run*Signature*

```
public final
void run()
```

When used as part of the internal mechanism activated by firing an async event, this method's detailed semantics are defined by the scheduler associated with this handler. The general outline is as follows:

```
enter initial memory area
while (fireCount > 0)
{
    [initiate release]
    fireCount--;
    try
    {
        handleAsyncEvent(value);
    }
    catch (Throwable th)
    {
        th.printStackTrace();
    }
    [effect completion]
}
leave initial memory area
```

All throwables from (or propagated through) `handleAsyncEvent`¹¹² are caught, a stack trace is printed and execution continues as if `handleAsyncEvent` had returned normally.

When it is directly invoked, this method invokes `handleAsyncEvent`¹¹³ repeatedly while the `fireCount` is greater than zero; e.g.,

```
while (getAndDecrementPendingFireCount() > 0)
```

```
{
    enter initial memory area
    handleAsyncEvent(value);
    leave initial memory area
}
```

however direct invocation of `run` is not recommended as it may interact with

¹¹²Section 8.4.3.7.2

¹¹³Section 8.4.3.7.2

the normal release of this handler.

Applications cannot override this method and thus should use the `logic` parameter at construction, or override `handleAsyncEvent()` in subclasses with the logic of the handler.

8.4.3.8 AsyncObjectEvent

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncObjectEvent
```

A new type of event that carries an object as a payload.

See [Section AsyncEvent](#)

8.4.3.8.1 Constructors

AsyncObjectEvent

Signature

```
public
  AsyncObjectEvent()
```

Create a new `AsyncEvent` object.

8.4.3.8.2 Methods

fire(PAYLOAD)

Signature

```
public
  void fire(PAYLOAD value)
```

throws `MITViolationException`,
`ArrivalTimeQueueOverflowException`

When enabled, fire this instance of `AsyncObjectEvent`. The asynchronous event handlers associated with this event will be released with the object passed by `fire`¹¹⁴. When no handlers are attached or this object is disabled the method does nothing, i.e., it skips the release.

- When the instance of `AsyncObjectEvent` is associated with more than one instance of `AsyncObjectEventHandler`¹¹⁵ with release parameters object of type `AperiodicParameters`¹¹⁶ and the execution of `fire`¹¹⁷ introduces the requirement to throw at least one type of exception, then all instances of `AsyncObjectEventHandler`¹¹⁸ not affected by the exception are handled normally.
- When this instance of `AsyncObjectEvent` is associated with more than one instance of `AsyncObjectEventHandler`¹¹⁹ with release parameters object of type `SporadicParameters`¹²⁰ and the execution of `fire`¹²¹ introduces the simultaneous requirement to throw more than one type of exception or error, then `MITViolationException`¹²² has precedence over `ArrivalTimeQueueOverflowException`¹²³.

Parameters

`value` is the payload passed to the event.

Throws

`MITViolationException` Thrown under the base priority scheduler's semantics when there is a handler associated with this event that has its MIT violated by the call to fire (and it has set the minimum inter-arrival time violation behavior to `MITViolationExcept`). Only the handlers which do not have their MITs violated are released in this situation.

`ArrivalTimeQueueOverflowException` when the queue of arrival time information overflows. Only the handlers which do not cause this exception to be thrown are released in this situation.

¹¹⁴Section 8.4.3.8.2

¹¹⁵Section 8.4.3.9

¹¹⁶Section 6.4.2.2

¹¹⁷Section 8.4.3.8.2

¹¹⁸Section 8.4.3.9

¹¹⁹Section 8.4.3.9

¹²⁰Section 6.4.2.14

¹²¹Section 8.4.3.8.2

¹²²Section 14.3.2.6

¹²³Section 14.3.2.1

8.4.3.9 AsyncObjectEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncObjectEventHandler
```

A version of [AsyncBaseEventHandler](#)¹²⁴ that carries an `Object` value as payload.

8.4.3.9.1 Constructors

AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer)

Signature

```
public
AsyncObjectEventHandler(SchedulingParameters scheduling,
                       ReleaseParameters release,
                       MemoryParameters memory,
                       MemoryArea area,
                       SchedulingGroup group,
                       ConfigurationParameters sizing,
                       java.util.function.Consumer< PAYLOAD> logic)
```

Create an asynchronous event handler that receives a `Long` payload with each fire.

Parameters

- `scheduling` parameters for the new handler.
- `release` parameters for the new handler.
- `memory` parameters for the new handler.
- `area` initial memory area for the new handler.
- `group` parameters for the new handler.
- `sizing` parameters for the new handler.

¹²⁴Section [8.4.3.3](#)

logic is the logic to run for each fire.

AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, Consumer)

Signature

```
public
AsyncObjectEventHandler(SchedulingParameters scheduling,
                        ReleaseParameters release,
                        java.util.function.Consumer< PAYLOAD> logic)
```

Calling this constructor is equivalent to calling `AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer)`¹²⁵ with arguments (scheduling, release, null, null, null, null, logic).

AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters)

Signature

```
public
AsyncObjectEventHandler(SchedulingParameters scheduling,
                        ReleaseParameters release)
```

Calling this constructor is equivalent to calling `AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer)`¹²⁶ with arguments (scheduling, release, null, null, null, null, null).

AsyncObjectEventHandler(Consumer)

Signature

```
public
AsyncObjectEventHandler(java.util.function.Consumer< PAYLOAD> logic)
```

¹²⁵Section 8.4.3.9.1

¹²⁶Section 8.4.3.9.1

Calling this constructor is equivalent to calling `AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer)`¹²⁷ with arguments (null, null, null, null, null, null, null, null, logic).

Parameters

logic is the function to call on the object received.

AsyncObjectEventHandler

Signature

```
public
AsyncObjectEventHandler()
```

Create an instance of `AsyncObjectEventHandler` with default values for all parameters.

See [Section AsyncObjectEventHandler\(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer\)](#)

8.4.3.9.2 Methods

peekPending

Signature

```
public
PAYLOAD peekPending()
throws IllegalStateException
```

Throws

`IllegalStateException` when the fire count is zero.

Returns

The object reference at the head of the queue of object references to be passed to `handleAsyncEvent`¹²⁸.

¹²⁷Section [8.4.3.9.1](#)

¹²⁸Section ??

run*Signature*

```
public final
void run()
```

When used as part of the internal mechanism activated by firing an async event, this method's detailed semantics are defined by the scheduler associated with this handler. The general outline is:

```
enter initial memory area
while (fireCount > 0)
{
    [initiate release]
    fireCount--;
    try { handleAsyncEvent(value); }
    catch (Throwable th) { th.printStackTrace(); }
    [effect completion]
}
leave initial memory area
```

All throwables from (or propagated through) `handleAsyncEvent`¹²⁹ are caught, a stack trace is printed and execution continues as if `handleAsyncEvent` had returned normally.

When it is directly invoked, this method invokes `handleAsyncEvent`¹³⁰ repeatedly while the `fireCount` is greater than zero; e.g.,

```
while (getAndDecrementPendingFireCount() > 0)
```

```
{
    enter initial memory area
    handleAsyncEvent(value);
    leave initial memory area
}
```

however direct invocation of `run` is not recommended as it may interact with the normal release of this handler.

Applications cannot override this method and thus should use the `logic` parameter at construction, or override `handleAsyncEvent` in subclasses with the logic of the handler.

¹²⁹Section ??

¹³⁰Section ??

8.4.3.10 BoundAsyncEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncEventHandler
      javax.realtime.BoundAsyncEventHandler
```

Interfaces

```
BoundAsyncBaseEventHandler
```

A bound asynchronous event handler is an instance of [AsyncEventHandler](#)¹³¹ that is permanently bound to a dedicated realtime thread. Bound asynchronous event handlers are for use in situations where the added timeliness is worth the overhead of dedicating an individual realtime thread to the handler. Individual server realtime threads can only be dedicated to a single bound event handler.

8.4.3.10.1 Constructors

BoundAsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)

Signature

```
public
BoundAsyncEventHandler(SchedulingParameters scheduling,
                      ReleaseParameters release,
                      MemoryParameters memory,
                      MemoryArea area,
                      SchedulingGroup group,
                      ConfigurationParameters sizing,
                      Runnable logic)
```

BoundAsyncEventHandler(SchedulingParameters, ReleaseParameters, Runnable)

¹³¹Section [8.4.3.5](#)

Signature

```
public
BoundAsyncEventHandler(SchedulingParameters scheduling,
                       ReleaseParameters release,
                       Runnable logic)
```

BoundAsyncEventHandler(SchedulingParameters, ReleaseParameters)*Signature*

```
public
BoundAsyncEventHandler(SchedulingParameters scheduling,
                       ReleaseParameters release)
```

BoundAsyncEventHandler(Runnable)*Signature*

```
public
BoundAsyncEventHandler(Runnable logic)
```

BoundAsyncEventHandler*Signature*

```
public
BoundAsyncEventHandler()
```

Create an instance of `BoundAsyncEventHandler` using default values. This constructor is equivalent to `BoundAsyncEventHandler(null, null, null, null, null, false, null)`

8.4.3.11 BoundAsyncLongEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncLongEventHandler
      javax.realtime.BoundAsyncLongEventHandler
```

Interfaces

```
BoundAsyncBaseEventHandler
```

A bound asynchronous event handler is an instance of [AsyncLongEventHandler](#)¹³² that is permanently bound to a dedicated realtime thread. Bound asynchronous event handlers are for use in situations where the added timeliness is worth the overhead of dedicating an individual realtime thread to the handler. Individual server realtime threads can only be dedicated to a single bound event handler.

8.4.3.11.1 Constructors

BoundAsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)

Signature

```
public
BoundAsyncLongEventHandler(SchedulingParameters scheduling,
                           ReleaseParameters release,
                           MemoryParameters memory,
                           MemoryArea area,
                           SchedulingGroup group,
                           ConfigurationParameters sizing,
                           LongConsumer logic)
```

Create an instance of `BoundAsyncLongEventHandler` which specifies all possible parameters.

Parameters

`scheduling` determines how it should be scheduled

¹³²Section [8.4.3.7](#)

release determines how it should be released
memory determinate how it should use memory
group is the **SchedulingGroup** it should use.
sizing is for sizing execution resources.
logic is to be run when its event is handled.

BoundAsyncLongEventHandler(SchedulingParameters, ReleaseParameters, LongConsumer)

Signature

```
public
BoundAsyncLongEventHandler(SchedulingParameters scheduling,
                           ReleaseParameters release,
                           LongConsumer logic)
```

BoundAsyncLongEventHandler(SchedulingParameters, ReleaseParameters)

Signature

```
public
BoundAsyncLongEventHandler(SchedulingParameters scheduling,
                           ReleaseParameters release)
```

BoundAsyncLongEventHandler(LongConsumer)

Signature

```
public
BoundAsyncLongEventHandler(LongConsumer logic)
```

BoundAsyncLongEventHandler

Signature

```
public
BoundAsyncLongEventHandler()
```

Create an instance of `BoundAsyncLongEventHandler` using default values. This constructor is equivalent to `BoundAsyncLongEventHandler(null, null, null, null, null, false, null)`

8.4.3.12 BoundAsyncObjectEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncObjectEventHandler
      javax.realtime.BoundAsyncObjectEventHandler
```

Interfaces

```
BoundAsyncBaseEventHandler
```

A bound asynchronous event handler is an instance of `AsyncObjectEventHandler`¹³³ that is permanently bound to a dedicated realtime thread. Bound asynchronous event handlers are for use in situations where the added timeliness is worth the overhead of dedicating an individual realtime thread to the handler. Individual server realtime threads can only be dedicated to a single bound event handler.

8.4.3.12.1 Constructors

BoundAsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, ProcessingGroup, ConfigurationParameters, Consumer)

Signature

```
public
BoundAsyncObjectEventHandler(SchedulingParameters scheduling,
                             ReleaseParameters release,
                             MemoryParameters memory,
                             MemoryArea area,
```

¹³³Section 8.4.3.9

```
ProcessingGroup group,
ConfigurationParameters sizing,
java.util.function.Consumer< Payload> logic)
```

Parameters

```
scheduling
release
memory
group
sizing
logic
```

BoundAsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, Consumer)*Signature*

```
public
BoundAsyncObjectEventHandler(SchedulingParameters scheduling,
                             ReleaseParameters release,
                             java.util.function.Consumer< Payload> logic)
```

BoundAsyncObjectEventHandler(SchedulingParameters, ReleaseParameters)*Signature*

```
public
BoundAsyncObjectEventHandler(SchedulingParameters scheduling,
                             ReleaseParameters release)
```

BoundAsyncObjectEventHandler(Consumer)*Signature*

```
public
```



```
BoundAsyncObjectEventHandler(java.util.function.Consumer< Payload> logic)
```

BoundAsyncObjectEventHandler

Signature

```
public  
BoundAsyncObjectEventHandler()
```

Create an instance of `BoundAsyncObjectEventHandler` using default values. This constructor is equivalent to `BoundAsyncObjectEventHandler(null, null, null, null, null, null)`

8.5 Rationale

The design of the asynchronous event handling facilities was intended to provide the necessary functionality while allowing efficient implementations and catering for a variety of realtime applications. In particular, in some realtime systems there may be a large number of potential events and event handlers (numbering in the thousands or perhaps even the tens of thousands), although at any given time only a small number will be used. Thus it would not be appropriate to dedicate a realtime thread to each event handler. The RTSJ addresses this issue by allowing the programmer to specify an event handler either as not bound to a specific realtime thread (the class `AsyncBaseEventHandler`) or alternatively as bound to a dedicated realtime thread (the interface `BoundAsyncBaseEventHandler`). The RTSJ does not define at what point a non-bound event handler is bound to a realtime thread for its execution. Events are dataless: the fire method does not pass any data to the handler. This was intentional in the interest of simplicity and efficiency.

The ability to trigger an ATC in a schedulable is necessary in many kinds of realtime applications but must be designed carefully in order to minimize the risks of problems such as data structure corruption and deadlock. There is, invariably, a tension between the desire to cause an ATC to be immediate, and the desire to ensure that certain sections of code are executed to completion.

One basic decision was to allow ATC in a method only if the method explicitly permits this. The default of no ATC is reasonable, since legacy code might be written expecting no ATC, and asynchronously aborting the execution of such a method could lead to unpredictable results. Since the natural way to model ATC is with an exception (`AsynchronouslyInterruptedException`), the way that a method

indicates its susceptibility to ATC is by including **AsynchronouslyInterruptedException** in its **throws** clause. Causing this exception to be thrown in a realtime thread **t** as an effect of calling **t.interrupt()** was a natural extension of the semantics of **interrupt** as currently defined by **java.lang.Thread**.

One ATC-deferred section is **synchronized** code. This is a context that needs to be executed completely in order to ensure a program operates correctly. If **synchronized** code were aborted, a shared object could be left in an inconsistent state. Note that by making **synchronized** code ATC-deferred, this specification avoids the problems that caused **Thread.stop()** to be deprecated and that have made the use of **Thread.destroy()**, (now also deprecated in Java 1.5) prone to deadlock. If **synchronized** code calls an AI-method and an associated AIE is generated, then if no appropriate handler is present in the **synchronized** code, the AIE will propagate through the code.

Constructors and **finally** clauses are subject to interruption if the program indicates so. However, if a constructor is aborted, an object might be only partially initialized. If the execution of a **finally** clause in an AI-method is aborted, needed cleanup code might not be performed. Indeed, a **finally** clause in an aborted AI-method will not be executed at all if the abort occurs before its execution begins. It is the programmer's responsibility to ensure that executing these constructs either does not induce unwanted ATC latency (if ATCs are not allowed) or does not produce undesirable results (if ATCs are allowed).

A potential problem with using the exception mechanism to model ATC is that a method with a "catch-all" handler (for example a **catch** clause identifying **Exception** or even **Throwable** as the exception class) can inadvertently intercept an exception intended for a caller. This problem is avoided by having special semantics for catching an AIE. Even though a **catch** clause may catch an AIE, the exception will be propagated unless the handler invokes the **happened** method from AIE. Thus, if a schedulable is asynchronously interrupted while in a **try** block that has a handler such as

```
catch (Throwable e) return;
```

the AIE will remain pending and will be thrown next time control enters or returns to an AI method.

This specification does not provide a special mechanism for terminating a realtime thread; ATC can be used to achieve this effect. This means that, by default, a realtime thread cannot be asynchronously terminated; to support asynchronous termination it needs to enter methods that are AI enabled at frequent intervals. Allowing termination as the default would have been questionable, bringing the same insecurities that are found in **Thread.stop()** and **Thread.destroy()**.

Chapter 9

Time

9.1 Overview

Realtime systems must be able to handle both very short time durations and very long ones. They also need to distinguish between relative time—a duration of time—and absolute time. Simply using a primitive integral value, such as `int` or `long`, does not provide the necessary range. Floating point primitive values, such as `float` and `double`, do not provide the necessary precision. Neither provides any type safety. This specification addresses this by requiring three time classes: `HighResolutionTime`, `AbsoluteTime`, and `RelativeTime`, where `HighResolutionTime` is the parent class of the other two.

Instances of `HighResolutionTime` may not be created, as the class exists to provide a common parent type for the other two classes. An instance of `AbsoluteTime` encapsulates an absolute time. An instance of `RelativeTime` encapsulates a point in time that is relative to some other absolute time value, which can be used to describe an unbound length of time.

All methods returning a time object come in both allocating and nonallocating forms. The classes

- enable describing a point in time with up to nanosecond accuracy and precision (actual accuracy and precision is dependent on the precision of the underlying system),
- enable the distinction between absolute points in time, and times relative to some starting point or an unbound time span, and
- provide simple arithmetic operations for using them.

All time handling is based on these classes.

9.2 Definitions

The following terms and abbreviations will be used.

A *time object* is an instance of `AbsoluteTime` or `RelativeTime`.

A *time object* is always associated with a `clock`. By default it is associated with the realtime clock.

The *Epoch* is the standard base time, conventionally January 1 00:00:00 GMT 1970. It is the point from which the realtime clock measures absolute time.

The *time value representation* is a compound format composed of 64 bits of millisecond timing, and 32 bits of nanoseconds within a millisecond. The millisecond constituent uses the 64 bits of a Java `long` while the nanosecond constituent uses the 32 bits of a Java `int`.

The *normalized (canonical) form* for time objects uniquely specifies the values for the millisecond and nanosecond components of a point in time, including the case of 0 milliseconds or 0 nanoseconds, and a negative time value, according to the following three rules:

- When both millisecond and nanosecond components are nonzero they have the same sign. The algebraic time value of the time object is the algebraic sum of the two components.
- The millisecond component represents the algebraic number of milliseconds in the time object, with a range of $[-2^{63}, 2^{63} - 1]$
- The nanosecond component represents the algebraic number of nanoseconds within a millisecond in the time object, that is $[-10^6 + 1, 10^6 - 1]$.

Instances of `HighResolutionTime` classes always hold a normalized form of a time value. Values that cannot be normalized are not valid; for example, (`MAX_LONG` milliseconds, `MAX_INT` nanoseconds) cannot be normalized and is an illegal value.

The following table has examples of normalized representations.

time in ns	millis	nanos
2000000	2	0
1999999	1	999999
1000001	1	1
1	0	1
0	0	0
-1	0	-1
-999999	0	-999999
-1000000	-1	0
-1000001	-1	-1

9.3 Semantics

The five main points below define the general semantics of the time classes. Semantics specific to particular classes, constructors, methods, and fields are in the class description and the constructor, method, and field detail sections.

- All time objects must maintain nanosecond precision and report their values in terms of millisecond and nanosecond constituents.
- Time objects must be constructed from other time objects, from millisecond/nanosecond values, from a `java.util.Date` or obtained as a result of invocations of methods on instances of the `Clock` class.
- Time objects maintain and report time values in normalized form, but the normalized form is not required for input parameter values. This allows computations individually with time constituent parts using the full *signed* range and restrictions of the underlying type.
 - Normalization is accomplished upon method invocation by methods that accept a time object represented with individual component parts, and executed as if the following hold.
 - * The nanosecond parameter value, which may be negative, is algebraically added to the scaled millisecond parameter value. The sign of the result provides the sign for any nonzero resulting component.
 - * The absolute of the result is then partitioned, giving the number of integral milliseconds for the millisecond component, while the remaining fractional part provides the number of nanoseconds for the nanosecond component.
 - * The resulting components are then represented, and reported when necessary, with the above computed sign.
 - Normalization is also performed on the result of operations by methods that perform time object addition and subtraction. Operations are executed using the appropriate arithmetic precision. If the final result of an operation can be represented in normalized form, then the operation must not throw arithmetic exceptions while producing intermediate results.
 - The results of time objects operations and the normalization of results of operations performed with `millis` and `nanos`, individually as Java `long` and Java `int` types respectively, are not always equivalent. This is due to the possibility of overflow for `nanos` values outside of the normalized nanosecond range, that is $[-10^6 + 1, 10^6 - 1]$, when performing operations as `int` types, while the same values could be handled with no overflow in time object operations.
 - When invoking setter methods that take as a parameter only one of the two time value components, the other component has implicitly the value of 0.

- Although logically a negative time may represent time before the Epoch or a negative time interval involved in time operations, an **Exception** may be thrown if a negative absolute time or a negative time interval is given as a parameter to methods. In general, the time values accepted by a method may be a subset of the full time values range, and depend on the method.
- A *time object* is always associated with a **clock**. By default it is associated with the realtime clock. Clocks are involved both in the setting as well as the usage of time objects, for example in comparisons.
- Methods are provided to facilitate the handling of time objects generically via the **HighResolutionTime** class. These methods allow the conversion, according to a **clock**, between **AbsoluteTime** objects and **RelativeTime** objects. These methods also allow the change of **clock** association of a time object. Note that the conversions depend on the time at which they are performed. The semantics of these operations are listed in the following table:

clock association and conversion this has clock_a and ms,ns	returned/updated object
this_is_absolute.absolute(clock_a)	clock_a
this_is_absolute.absolute(clock_b)	clock_b
this_is_absolute.absolute(null)	realtime_clock
this_is_absolute.relative(clock_a)	clock_a
this_is_absolute.relative(clock_b)	clock_b
this_is_absolute.relative(null)	realtime_clock
this_is_relative.relative(clock_a)	clock_a
this_is_relative.relative(clock_b)	clock_b
this_is_relative.relative(null)	realtime_clock
this_is_relative.absolute(clock_a)	clock_a
this_is_relative.absolute(clock_b)	clock_b
this_is_relative.absolute(null)	realtime_clock

- Time objects must implement the **Comparable** interface if it is available. The

`compareTo()` method must be implemented even if the interface is not available.

9.4 Package *javax.realtime*

9.4.1 Classes

9.4.1.1 *AbsoluteTime*

Inheritance

```
java.lang.Object
  javax.realtime.HighResolutionTime
    javax.realtime.AbsoluteTime
```

An object that represents a specific point in time given by milliseconds plus nanoseconds past some point in time fixed by the `clock`. For the default realtime clock the fixed point is the Epoch (January 1, 1970, 00:00:00 GMT). The correctness of the Epoch as a time base depends on the realtime clock synchronization with an external world time reference. This representation was designed to be compatible with the standard Java representation of an absolute time in the `java.util.Date` class.

A time object in normalized form represents negative time when both components are nonzero and negative, or one is nonzero and negative and the other is zero. For `add` and `subtract` negative values behave as they do in arithmetic.

9.4.1.1.1 Constructors

AbsoluteTime(*AbsoluteTime*, *Chronograph*)

Signature

```
public
AbsoluteTime(AbsoluteTime time,
              Chronograph chronograph)
throws IllegalArgumentException
```

Make a new *AbsoluteTime* object from the given *AbsoluteTime* object.

The clock association is made with the `chronograph` parameter. When `chronograph` is `null` the association is made with the default realtime clock.

Parameters

`time` The *AbsoluteTime* object which is the source for the copy.

chronograph The chronograph providing the association for the newly constructed object.

Throws

`IllegalArgumentException` when the `time` parameter is `null`.

AbsoluteTime(Chronograph)

Signature

```
public  
AbsoluteTime(Chronograph chronograph)
```

Equivalent to `new AbsoluteTime(0,0,chronograph)`.

The chronograph association is made with the `chronograph` parameter. When `chronograph` is `null` the association is made with the default realtime clock.

Parameters

chronograph The chronograph providing the association for the newly constructed object.

AbsoluteTime

Signature

```
public  
AbsoluteTime()
```

Equivalent to `new AbsoluteTime(0,0)`.

The clock association is implicitly made with the default realtime clock.

AbsoluteTime(AbsoluteTime)

Signature

```
public  
AbsoluteTime(AbsoluteTime time)  
throws IllegalArgumentException
```

Make a new `AbsoluteTime` object from the given `AbsoluteTime` object.

The new object will have the same clock association as the `time` parameter.

Parameters

`time` The `AbsoluteTime` object which is the source for the copy.

Throws

`IllegalArgumentException` when the `time` parameter is `null`.

`AbsoluteTime(Date)`

Signature

```
public  
AbsoluteTime(Date date)  
throws IllegalArgumentException
```

Equivalent to `new AbsoluteTime(date.getTime(),0)`. The clock association is implicitly made with the default realtime clock.

Parameters

`date` The `java.util.Date` representation of the time past the Epoch.

Throws

`IllegalArgumentException` when the `date` parameter is `null`.

`AbsoluteTime(Date, Chronograph)`

Signature

```
public  
AbsoluteTime(Date date,  
              Chronograph chronograph)  
throws IllegalArgumentException
```

Equivalent to `new AbsoluteTime(date.getTime(),0,chronograph)`.

Warning: While the `date` is used to set the milliseconds component of the new `AbsoluteTime` object (with nanoseconds component set to 0), the new object represents the `date` only when the `chronograph` parameter has an epoch equal to Epoch.

The clock association is made with the `chronograph` parameter. When `chronograph` is `null` the association is made with the default realtime clock.

Parameters

date The `java.util.Date` representation of the time past the Epoch.
chronograph The chronograph providing the association for the newly constructed object.

Throws

`IllegalArgumentException` when the `date` parameter is `null`.

AbsoluteTime(long, int)*Signature*

```
public  
AbsoluteTime(long millis,  
              int nanos)  
throws IllegalArgumentException
```

Construct an `AbsoluteTime` object with time millisecond and nanosecond components past the realtime clock's Epoch (00:00:00 GMT on January 1, 1970) based on the parameter `millis` plus the parameter `nanos`. The construction is subject to `millis` and `nanos` parameters normalization. When, after normalization, the time object is negative, the time represented by this is time before the Epoch of its [Chronograph](#)¹. The clock association is implicitly made with the default realtime clock.

Parameters

millis is the desired value for the millisecond component of **this**. The actual value is the result of parameter normalization.

nanos is the desired value for the nanosecond component of **this**. The actual value is the result of parameter normalization.

Throws

`IllegalArgumentException` when there is an overflow in the millisecond component when normalizing.

AbsoluteTime(long, int, Chronograph)*Signature*

```
public  
AbsoluteTime(long millis,
```

¹Section [10.4.1.2](#)

```
        int nanos,  
        Chronograph chronograph)  
    throws IllegalArgumentException
```

Construct an `AbsoluteTime` object with time millisecond and nanosecond components past the epoch for `chronograph`.

The value of the `AbsoluteTime` instance is based on the parameter `millis` plus the parameter `nanos`. The construction is subject to `millis` and `nanos` parameters normalization. When, after normalization, the time object is negative, the time represented by this is time before `this` chronograph's `epoch`. The chronograph association is made with the `chronograph` parameter. When `chronograph` is null the association is made with the default realtime clock.

Note: The start of a chronograph's epoch is an attribute of the chronograph. It is defined as the Epoch (00:00:00 GMT on Jan 1, 1970) for the default realtime clock, but other classes of chronograph may define other epochs.

Parameters

millis The desired value for the millisecond component of `this`. The actual value is the result of parameter normalization.

nanos The desired value for the nanosecond component of `this`. The actual value is the result of parameter normalization.

chronograph The chronograph providing the association for the newly constructed object.

Throws

`IllegalArgumentException` when there is an overflow in the millisecond component when normalizing.

9.4.1.1.2 Methods

absolute(Chronograph)

Signature

```
public  
javax.realtime.AbsoluteTime absolute(Chronograph chronograph)
```

Return a copy of `this` modified when necessary to have the specified chronograph association. A new object is allocated for the result. This method is the implementation of the abstract method of the `HighResolutionTime` base class. No conversion into `AbsoluteTime` is needed in this case. The chronograph association of the result

is with the `chronograph` passed as a parameter. When `chronograph` is `null` the association is made with the default realtime clock.

Parameters

chronograph The `chronograph` parameter is used only as the new chronograph association with the result, since no conversion is needed.

Returns

The copy of `this` in a newly allocated `AbsoluteTime` object, associated with the `chronograph` parameter.

absolute(Chronograph, AbsoluteTime)

Signature

```
public
javax.realtime.AbsoluteTime absolute(Chronograph chronograph,
                                     AbsoluteTime dest)
```

relative(Clock)

Signature

```
public
javax.realtime.RelativeTime relative(Clock clock)
throws ArithmeticException
```

Convert the time of `this` to a relative time, using the given instance of `Clock`² to determine the current time. The calculation is the current time indicated by the given instance of `Clock`³ subtracted from the time given by `this`. When `clock` is `null` the default realtime clock is assumed. A destination object is allocated to return the result. The clock association of the result is with the `clock` passed as a parameter.

Parameters

clock The instance of `Clock`⁴ used to convert the time of `this` into relative time, and the new clock association for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

²Section 10.4.2.1

³Section 10.4.2.1

⁴Section 10.4.2.1

The `RelativeTime` conversion in a newly allocated object, associated with the `clock` parameter.

relative(Chronograph)

Signature

```
public  
javax.realtime.RelativeTime relative(Chronograph chronograph)
```

Convert the time of `this` to a relative time, using the given instance of [Chronograph⁵](#) to determine the current time. The calculation is the current time indicated by the given instance of [Chronograph⁶](#) subtracted from the time given by `this`. When `chronograph` is `null` the default realtime clock is assumed. A destination object is allocated to return the result. The clock association of the result is with the `chronograph` passed as a parameter.

Parameters

`chronograph` The instance of [Chronograph⁷](#) used to convert the time of `this` into relative time, and the new clock association for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

The `RelativeTime` conversion in a newly allocated object, associated with the `chronograph` parameter.

relative(Chronograph, RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime relative(Chronograph chronograph,  
                                     RelativeTime dest)
```

Convert the time of `this` to a relative time, using the given instance of [Chronograph⁸](#) to determine the current time. The calculation is the current time indicated by the given instance of [Chronograph⁹](#) subtracted from the time given by `this`. When `chronograph` is `null` the default realtime clock is assumed. When `dest` is

⁵Section [10.4.1.2](#)

⁶Section [10.4.1.2](#)

⁷Section [10.4.1.2](#)

⁸Section [10.4.1.2](#)

⁹Section [10.4.1.2](#)

not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The clock association of the result is with the `chronograph` passed as a parameter.

Parameters

`chronograph` The instance of [Chronograph](#)¹⁰ used to convert the time of `this` into relative time, and the new clock association for the result.

`dest` When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

The `RelativeTime` conversion in `dest` when `dest` is not `null`, otherwise the result is returned in a newly allocated object. It is associated with the `chronograph` parameter.

add(long, int)

Signature

```
public
javax.realtime.AbsoluteTime add(long millis,
                                int nanos)
throws ArithmeticException
```

Create a new object representing the result of adding `millis` and `nanos` to the values from `this` and normalizing the result. The result will have the same clock association as `this`.

Parameters

`millis` The number of milliseconds to be added to `this`.

`nanos` The number of nanoseconds to be added to `this`.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

A new `AbsoluteTime` object whose time is the normalization of `this` plus `millis` and `nanos`.

add(long, int, AbsoluteTime)

Signature

¹⁰Section [10.4.1.2](#)

```
public
javax.realtime.AbsoluteTime add(long millis,
                                int nanos,
                                AbsoluteTime dest)

throws ArithmeticException
```

Return an object containing the value resulting from adding `millis` and `nanos` to the values from `this` and normalizing the result. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The result will have the same clock association as `this`, and the clock association with `dest` is ignored.

Parameters

`millis` The number of milliseconds to be added to `this`.

`nanos` The number of nanoseconds to be added to `this`.

`dest` When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

the result of the normalization of `this` plus `millis` and `nanos` in `dest` when `dest` is not `null`, otherwise the result is returned in a newly allocated object.

add(RelativeTime)

Signature

```
public
javax.realtime.AbsoluteTime add(RelativeTime time)
throws ArithmeticException,
       IllegalArgumentException
```

Create a new instance of `AbsoluteTime` representing the result of adding `time` to the value of `this` and normalizing the result. The `clock` associated with `this` and the `clock` associated with the `time` parameter must be the same, and such association is used for the result.

Parameters

`time` The time to add to `this`.

Throws

`IllegalArgumentException` when the `clock` associated with `this` and the `clock` associated with the `time` parameter are different, or when the `time` parameter is `null`.

ArithmeticException when the result does not fit in the normalized format.

Returns

A new **AbsoluteTime** object whose time is the normalization of **this** plus the parameter **time**.

add(RelativeTime, AbsoluteTime)

Signature

```
public
javax.realtime.AbsoluteTime add(RelativeTime time,
                                AbsoluteTime dest)

throws ArithmeticException,
        IllegalArgumentException
```

Return an object containing the value resulting from adding **time** to the value of **this** and normalizing the result. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result. The **clock** associated with **this** and the **clock** associated with the **time** parameter must be the same, and such association is used for the result. The **clock** associated with the **dest** parameter is ignored.

Parameters

time The time to add to **this**.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

IllegalArgumentException when the **clock** associated with **this** and the **clock** associated with the **time** parameter are different, or when the **time** parameter is **null**.

ArithmeticException when the result does not fit in the normalized format.

Returns

the result of the normalization of **this** plus the **RelativeTime** parameter **time** in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object.

getDate

Signature

```
public
java.util.Date getDate()
```

throws `UnsupportedOperationException`

Convert the time given by `this` to a `Date` format. Note that `Date` represents time as milliseconds so the nanoseconds of `this` will be lost.

Throws

`UnsupportedOperationException` when the clock associated with `this` does not have the concept of date.

Returns

A newly allocated `Date` object with a value of the time past the Epoch represented by `this`.

set(Date)

Signature

```
public
void set(Date date)
throws IllegalArgumentException
```

Change the time represented by `this` to that given by the parameter. Note that `Date` represents time as milliseconds so the nanoseconds of `this` will be set to 0. The clock association is implicitly made with the default realtime clock.

Parameters

`date` A reference to a `Date` which will become the time represented by `this` after the completion of this method.

Throws

`IllegalArgumentException` when the parameter `date` is `null`.

subtract(AbsoluteTime)

Signature

```
public
javax.realtime.RelativeTime subtract(AbsoluteTime time)
throws IllegalArgumentException,
    ArithmeticException
```

Create a new instance of `RelativeTime` representing the result of subtracting `time` from the value of `this` and normalizing the result. The `clock` associated with `this` and the `clock` associated with the `time` parameter must be the same, and such association is used for the result.

Parameters

time The time to subtract from **this**.

Throws

IllegalArgumentException when the **clock** associated with **this** and the **clock** associated with the **time** parameter are different, or when the **time** parameter is **null**.

ArithmeticException when the result does not fit in the normalized format.

Returns

A new **RelativeTime** object whose time is the normalization of **this** minus the **AbsoluteTime** parameter **time**.

subtract(AbsoluteTime, RelativeTime)

Signature

```
public
    javax.realtime.RelativeTime subtract(AbsoluteTime time,
                                         RelativeTime dest)

    throws IllegalArgumentException,
           ArithmeticException
```

Return an object containing the value resulting from subtracting **time** from the value of **this** and normalizing the result. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result. The **clock** associated with **this** and the **clock** associated with the **time** parameter must be the same, and such association is used for the result. The **clock** associated with the **dest** parameter is ignored.

Parameters

time The time to subtract from **this**.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

IllegalArgumentException when the **clock** associated with **this** and the **clock** associated with the **time** parameter are different, or when the **time** parameter is **null**.

ArithmeticException when the result does not fit in the normalized format.

Returns

the result of the normalization of **this** minus the **AbsoluteTime** parameter **time** in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object.

subtract(RelativeTime)

Signature

```
public
javax.realtime.AbsoluteTime subtract(RelativeTime time)
throws IllegalArgumentException,
    ArithmeticException
```

Create a new instance of `AbsoluteTime` representing the result of subtracting `time` from the value of `this` and normalizing the result. The `clock` associated with `this` and the `clock` associated with the `time` parameter must be the same, and such association is used for the result.

Parameters

`time` The time to subtract from `this`.

Throws

`IllegalArgumentException` when the `clock` associated with `this` and the `clock` associated with the `time` parameter are different, or when the `time` parameter is `null`.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

A new `AbsoluteTime` object whose time is the normalization of `this` minus the parameter `time`.

subtract(RelativeTime, AbsoluteTime)

Signature

```
public
javax.realtime.AbsoluteTime subtract(RelativeTime time,
                                     AbsoluteTime dest)
throws IllegalArgumentException,
    ArithmeticException
```

Return an object containing the value resulting from subtracting `time` from the value of `this` and normalizing the result. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The `clock` associated with `this` and the `clock` associated with the `time` parameter must be the same, and such association is used for the result. The `clock` associated with the `dest` parameter is ignored.

Parameters

`time` The time to subtract from `this`.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

IllegalArgumentException when the **clock** associated with **this** and the **clock** associated with the **time** parameter are different, or when the **time** parameter is **null**.

ArithmeticException when the result does not fit in the normalized format.

Returns

the result of the normalization of **this** minus the **RelativeTime** parameter **time** in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object.

toString

Signature

```
public  
java.lang.String toString()
```

Create a printable string of the time given by **this**.

The string shall be a decimal representation of the milliseconds and nanosecond values; formatted as follows "(2251 ms, 750000 ns)"

Returns

String object converted from the time given by **this**.

9.4.1.2 HighResolutionTime

Inheritance

```
java.lang.Object  
    javax.realtime.HighResolutionTime
```

Interfaces

```
Comparable  
Cloneable
```

Class **HighResolutionTime** is the base class for **AbsoluteTime** and **RelativeTime**. It can be used to express time with nanosecond resolution. This class is never used directly; it is abstract and has no public constructor. Instead, one of its subclasses **AbsoluteTime**¹¹ or **RelativeTime**¹² should be used. When an API is defined that

¹¹Section 9.4.1.1

¹²Section 9.4.1.3

has a `HighResolutionTime` as a parameter, it can take either an absolute or a relative time and will do something appropriate.

9.4.1.2.1 Methods

`waitForObject(Object, HighResolutionTime)`

Signature

```
public static
boolean waitForObject(Object target,
                      javax.realtime.HighResolutionTime<?> time)
throws InterruptedException,
       IllegalMonitorStateException,
       IllegalArgumentException,
       UnsupportedOperationException
```

Behaves like `target.wait()` but with the enhancement that it waits with a precision of `HighResolutionTime` and returns true when the associated notify was received, false when timeout occurred. As for `target.wait()`, there is the possibility of spurious wakeup behavior.

The wait `time` may be relative or absolute, and it is controlled by the `clock` associated with it. When the wait `time` is relative, then the calling thread is blocked waiting on `target` for the amount of time given by `time`, and measured by the associated `clock`. When the wait `time` is absolute, then the calling thread is blocked waiting on `target` until the indicated `time` value is reached by the associated `clock`.

Parameters

target The object on which to wait. The current thread must have a lock on the object.

time The time for which to wait. When it is `RelativeTime(0,0)` then wait indefinitely. When it is `null` then wait indefinitely.

Throws

`InterruptedException` when this schedulable is interrupted by `RealtimeThread.interrupt`¹³ or `AsynchronouslyInterruptedException.fire`¹⁴ while it is waiting.

`IllegalArgumentException` when `time` represents a relative time less than zero.

¹³Section 5.3.2.2.2

¹⁴Section 8.4.2.1.2

`IllegalMonitorStateException` when `target` is not locked by the caller.

`UnsupportedOperationException` when the wait operation is not supported using the `clock` associated with `time`.

Returns

`true` when the notify was received before the timeout; `false` otherwise.

equals(T)

Signature

```
public  
boolean equals(T time)
```

Returns `true` when the argument `time` has the same type and values as `this`.

Equality includes `clock` association.

Parameters

`time` Value compared to `this`.

Returns

`true` when the parameter `time` is of the same type and has the same values as `this`.

getClock

Signature

```
public final  
java.xml.realtime.Clock getClock()  
throws UnsupportedOperationException
```

Returns a reference to the `clock` associated with `this`.

Throws

`UnsupportedOperationException` when the time is based on a [Chronograph](#)¹⁵ that is not a [Clock](#)¹⁶.

Returns

A reference to the `clock` associated with `this`.

getChronograph

Signature

¹⁵Section [10.4.1.2](#)

¹⁶Section [10.4.2.1](#)

```
public final  
    javax.realtime.Chronograph getChronograph()
```

Get a reference to the [Chronograph](#)¹⁷ associated with **this**.

Returns

A reference to the [Chronograph](#)¹⁸ associated with **this**.

getMilliseconds

Signature

```
public final  
    long getMilliseconds()
```

Get the milliseconds component of **this**.

Returns

The milliseconds component of the time represented by **this**.

getNanoseconds

Signature

```
public final  
    int getNanoseconds()
```

Get the nanoseconds component of **this**.

Returns

The nanoseconds component of the time represented by **this**.

set(T)

Signature

```
public  
    void set(T time)
```

Change the value represented by **this** to that of the given **time**. The **clock** associated with **this** is set to be the **clock** associated with the **time** parameter.

Parameters

time The new value for **this**.

¹⁷Section [10.4.1.2](#)

¹⁸Section [10.4.1.2](#)

Throws

`IllegalArgumentException` when the parameter `time` is `null`.

`ClassCastException` when the type of `this` and the type of the parameter `time` are not the same.

set(long)*Signature*

```
public  
void set(long millis)
```

Sets the millisecond component of `this` to the given argument, and the nanosecond component of `this` to 0. This method is equivalent to `set(millis, 0)`.

Parameters

`millis` This value shall be the value of the millisecond component of `this` at the completion of the call.

set(long, int)*Signature*

```
public  
void set(long millis,  
         int nanos)  
throws IllegalArgumentException
```

Sets the millisecond and nanosecond components of `this`. The setting is subject to parameter normalization. When after normalization the time is negative then the time represented by `this` is set to a negative value, but note that negative times are not supported everywhere. For instance, a negative relative time is an invalid value for a periodic thread's period.

Parameters

`millis` The desired value for the millisecond component of `this` at the completion of the call. The actual value is the result of parameter normalization.

`nanos` The desired value for the nanosecond component of `this` at the completion of the call. The actual value is the result of parameter normalization.

Throws

`IllegalArgumentException` when there is an overflow in the millisecond component while normalizing.

hashCode

Signature

```
public  
int hashCode()
```

Returns a hash code for this object in accordance with the general contract of **name**. Time objects that are **equals**¹⁹ equal have the same hash code.

Returns

The hashcode value for this instance.

clone

Signature

```
public  
java.lang.Object clone()
```

Return a clone of **this**. This method should behave effectively as when it constructed a new object with the visible values of **this**. The new object is created in the current allocation context.

compareTo(T)

Signature

```
public  
int compareTo(T time)
```

Compares **this** `HighResolutionTime` with the specified `HighResolutionTime` **time**.

Parameters

time Compares with the time of **this**.

Throws

`ClassCastException` when the **time** parameter is not of the same class as **this**.

`IllegalArgumentException` when the **time** parameter is not associated with the same clock as **this**, or when the **time** parameter is `null`.

Returns

¹⁹Section [9.4.1.2.1](#)

a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than `time`.

equals(Object)

Signature

```
public  
boolean equals(Object object)
```

Returns `true` when the argument `object` has the same type and values as `this`. Equality includes `clock` association.

Parameters

`object` Value compared to `this`.

Returns

`true` when the parameter `object` is of the same type and has the same values as `this`.

absolute(Chronograph)

Signature

```
public abstract  
javax.realtime.AbsoluteTime absolute(Chronograph chronograph)
```

Convert the time of `this` to an absolute time, using the given instance of [Chronograph](#)²⁰ to determine the current time when necessary. When `chronograph` is `null` the realtime clock is assumed.

A destination object is allocated to return the result. The clock association of the result is the `clock` passed as a parameter. See the subclass comments for more specific information.

Parameters

`chronograph` is the instance of [Chronograph](#)²¹ used to convert the time of `this` into absolute time, and the new chronograph association for the result.

Returns

The `AbsoluteTime` conversion in a newly allocated object, associated with the `clock` parameter.

²⁰Section [10.4.1.2](#)

²¹Section [10.4.1.2](#)

absolute(Chronograph, AbsoluteTime)

Signature

```
public abstract  
    javax.realtime.AbsoluteTime absolute(Chronograph chronograph,  
                                         AbsoluteTime dest)
```

Convert the time of **this** to an absolute time, using the given instance of **Chronograph**²² to determine the current time when necessary. When **chronograph** is **null** the realtime chronograph is assumed. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result. The chronograph association of the result is the **chronograph** passed as a parameter. See the subclass comments for more specific information.

Parameters

chronograph The instance of **Chronograph**²³ used to convert the time of **this** into absolute time, and the new chronograph association for the result.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Returns

The **AbsoluteTime** conversion in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object. It is associated with the **chronograph** parameter.

relative(Chronograph)

Signature

```
public abstract  
    javax.realtime.RelativeTime relative(Chronograph chronograph)
```

Convert the time of **this** to a relative time, using the given instance of **Chronograph**²⁴ to determine the current time when necessary. When **chronograph** is **null** the realtime chronograph is assumed. A destination object is allocated to return the result. The chronograph association of the result is the **chronograph** passed as a parameter. See the subclass comments for more specific information.

Parameters

²²Section 10.4.1.2

²³Section 10.4.1.2

²⁴Section 10.4.1.2

chronograph The instance of [Chronograph](#)²⁵ used to convert the time of **this** into relative time, and the new chronograph association for the result.

Returns

The **RelativeTime** conversion in a newly allocated object, associated with the **chronograph** parameter.

relative(Chronograph, RelativeTime)

Signature

```
public abstract  
javax.realtime.RelativeTime relative(Chronograph chronograph,  
                                     RelativeTime dest)
```

Convert the time of **this** to a relative time, using the given instance of [Chronograph](#)²⁶ to determine the current time when necessary. When **chronograph** is **null** the realtime chronograph is assumed. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result. The chronograph association of the result is the **chronograph** passed as a parameter. See the subclass comments for more specific information.

Parameters

chronograph The instance of [Chronograph](#)²⁷ used to convert the time of **this** into relative time, and the new chronograph association for the result.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Returns

The [RelativeTime](#)²⁸ conversion in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object.

9.4.1.3 RelativeTime

Inheritance

```
java.lang.Object  
  javax.realtime.HighResolutionTime  
    javax.realtime.RelativeTime
```

²⁵Section [10.4.1.2](#)

²⁶Section [10.4.1.2](#)

²⁷Section [10.4.1.2](#)

²⁸Section [9.4.1.3](#)

An object that represents a time interval $\text{milliseconds}/10^3 + \text{nanoseconds}/10^9$ seconds long. It generally is used to represent a time relative to now.

The time interval is kept in normalized form. The range goes from $[(-2^{63}) \text{ milliseconds} + (-10^6+1) \text{ nanoseconds}]$ to $[(2^{63}-1) \text{ milliseconds} + (10^6-1) \text{ nanoseconds}]$.

A negative interval relative to now represents time in the past. For `add` and `subtract` negative values behave as they do in arithmetic.

9.4.1.3.1 Constructors

RelativeTime

Signature

```
public  
RelativeTime()
```

Equivalent to `new RelativeTime(0,0)`.

The clock association is implicitly made with the realtime clock.

RelativeTime(Chronograph)

Signature

```
public  
RelativeTime(Chronograph chronograph)
```

Equivalent to `new RelativeTime(0,0,chronograph)`.

The chronograph association is made with the `chronograph` parameter. When `chronograph` is null the association is made with the default realtime clock.

Parameters

chronograph The chronograph providing the association for the newly constructed object.

RelativeTime(long, int)

Signature

```
public  
RelativeTime(long millis,  
              int nanos)  
throws IllegalArgumentException
```

Construct a `RelativeTime` object representing an interval based on the parameter `millis` plus the parameter `nanos`. The construction is subject to `millis` and `nanos` parameters normalization. When there is an overflow in the millisecond component when normalizing then an `IllegalArgumentException` will be thrown. The clock association is implicitly made with the realtime clock.

Parameters

millis The desired value for the millisecond component of `this`. The actual value is the result of parameter normalization.

nanos The desired value for the nanosecond component of `this`. The actual value is the result of parameter normalization.

Throws

`IllegalArgumentException` when there is an overflow in the millisecond component when normalizing.

`RelativeTime(long, int, Chronograph)`

Signature

```
public  
RelativeTime(long millis,  
              int nanos,  
              Chronograph chronograph)  
throws IllegalArgumentException
```

Construct a `RelativeTime` object representing an interval based on the parameter `millis` plus the parameter `nanos`. The construction is subject to `millis` and `nanos` parameters normalization. When there is an overflow in the millisecond component when normalizing then an `IllegalArgumentException` will be thrown.

The chronograph association is made with the `chronograph` parameter. When `chronograph` is `null` the association is made with the default realtime clock.

Parameters

millis The desired value for the millisecond component of `this`. The actual value is the result of parameter normalization.

nanos The desired value for the nanosecond component of `this`. The actual value is the result of parameter normalization.

chronograph The chronograph providing the association for the newly constructed object.

Throws

IllegalArgumentException when there is an overflow in the millisecond component when normalizing.

RelativeTime(RelativeTime)

Signature

```
public  
RelativeTime(RelativeTime time)
```

Make a new **RelativeTime** object from the given **RelativeTime** object. The new object will have the same clock association as the **time** parameter.

Parameters

time The **RelativeTime** object which is the source for the copy.

RelativeTime(RelativeTime, Chronograph)

Signature

```
public  
RelativeTime(RelativeTime time,  
             Chronograph chronograph)  
throws IllegalArgumentException
```

Make a new **RelativeTime** object from the given **RelativeTime** object.

The clock association is made with the **chronograph** parameter. When **chronograph** is **null** the association is made with the realtime clock.

Parameters

time The **RelativeTime** object which is the source for the copy.

chronograph The chronograph providing the association for the newly constructed object.

Throws

IllegalArgumentException when the **time** parameter is **null**.

9.4.1.3.2 Methods

add(long, int)

Signature

```
public
javax.realtime.RelativeTime add(long millis,
                                int nanos)

throws ArithmeticException
```

Create a new object representing the result of adding `millis` and `nanos` to the values from `this` and normalizing the result. The result will have the same clock association as `this`. An `ArithmeticException` is when the result does not fit in the normalized format.

Parameters

`millis` The number of milliseconds to be added to `this`.

`nanos` The number of nanoseconds to be added to `this`.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

A new `RelativeTime` object whose time is the normalization of `this` plus `millis` and `nanos`.

add(long, int, RelativeTime)

Signature

```
public
javax.realtime.RelativeTime add(long millis,
                                int nanos,
                                RelativeTime dest)

throws ArithmeticException
```

Return an object containing the value resulting from adding `millis` and `nanos` to the values from `this` and normalizing the result. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The result will have the same clock association as `this`, and the clock association with `dest` is ignored.

Parameters

`millis` The number of milliseconds to be added to `this`.

`nanos` The number of nanoseconds to be added to `this`.

`dest` When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

the result of the normalization of `this` plus `millis` and `nanos` in `dest` when `dest` is not null, otherwise the result is returned in a newly allocated object.

add(RelativeTime)*Signature*

```
public
javax.realtime.RelativeTime add(RelativeTime time)
throws IllegalArgumentException,
    ArithmeticException
```

Create a new instance of `RelativeTime` representing the result of adding `time` to the value of `this` and normalizing the result.

The `clock` associated with `this` and the `clock` associated with the `time` parameter are expected to be the same, and such association is used for the result.

Parameters

`time` The time to add to `this`.

Throws

`IllegalArgumentException` when the `clock` associated with `this` and the `clock` associated with the `time` parameter are different, or when the `time` parameter is null.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

A new `RelativeTime` object whose time is the normalization of `this` plus the parameter `time`.

add(RelativeTime, RelativeTime)*Signature*

```
public
javax.realtime.RelativeTime add(RelativeTime time,
                                RelativeTime dest)
throws IllegalArgumentException,
    ArithmeticException
```

Return an object containing the value resulting from adding `time` to the value of `this` and normalizing the result. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

The `clock` associated with `this` and the `clock` associated with the `time` parameter are expected to be the same, and such association is used for the result.

The `clock` associated with the `dest` parameter is ignored.

Parameters

`time` The time to add to `this`.

`dest` When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

`IllegalArgumentException` when the `clock` associated with `this` and the `clock` associated with the `time` parameter are different, or when the `time` parameter is `null`.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

the result of the normalization of `this` plus the `RelativeTime` parameter `time` in `dest` when `dest` is not `null`, otherwise the result is returned in a newly allocated object.

subtract(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime subtract(RelativeTime time)  
throws IllegalArgumentException,  
        ArithmeticException
```

Create a new instance of `RelativeTime` representing the result of subtracting `time` from the value of `this` and normalizing the result.

The `clock` associated with `this` and the `clock` associated with the `time` parameter are expected to be the same, and such association is used for the result.

Parameters

`time` The time to subtract from `this`.

Throws

`IllegalArgumentException` when the `clock` associated with `this` and the `clock` associated with the `time` parameter are different, or when the `time` parameter is `null`.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

A new `RelativeTime` object whose time is the normalization of `this` minus the parameter `time`.

subtract(RelativeTime, RelativeTime)

Signature

```
public
javax.realtime.RelativeTime subtract(RelativeTime time,
                                     RelativeTime dest)

throws IllegalArgumentException,
       ArithmeticException
```

Return an object containing the value resulting from subtracting the value of `time` from the value of `this` and normalizing the result. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

The `clock` associated with `this` and the `clock` associated with the `time` parameter are expected to be the same, and such association is used for the result.

The `clock` associated with the `dest` parameter is ignored.

Parameters

time The time to subtract from `this`.

dest When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

`IllegalArgumentException` when the when the `clock` associated with `this` and the `clock` associated with the `time` parameter are different, or when the `time` parameter is `null`.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

the result of the normalization of `this` minus the `RelativeTime` parameter `time` in `dest` when `dest` is not `null`, otherwise the result is returned in a newly allocated object.

scale(int)

Signature

```
public
javax.realtime.RelativeTime scale(int factor)
```

Change the length of this relative time by multiplying it by **factor**.

Parameters

factor by which to increase the time interval.

Returns

a new object with **value** of this scaled by **factor**.

scale(RelativeTime, int)

Signature

```
public  
javax.realtime.RelativeTime scale(RelativeTime time,  
                                   int factor)
```

Set **time** to the value of **this** time by multiplied by **factor**.

Parameters

time in which to store the results.

factor by which to increase the time interval.

Returns

time with the value of **this** scaled by **factor**

compareToZero

Signature

```
public  
int compareToZero()
```

Compare **this** to relative time zero returning the result of the comparison. Equivalent to `constantZero.compareTo(this)`

Returns

negative when **this** is less than zero, 0, when it is equal to zero and a positive when **this** is greater than zero.

toString

Signature

```
public  
java.lang.String toString()
```

Create a printable string of the time given by **this**.

The string shall be a decimal representation of the milliseconds and nanosecond values; formatted as follows "(2251 ms, 750000 ns)"

Returns

String object converted from the time given by **this**.

compareTo(RelativeTime)

Signature

```
public  
int compareTo(RelativeTime time)
```

absolute(Chronograph)

Signature

```
public  
javax.realtime.AbsoluteTime absolute(Chronograph chronograph)
```

See Section [HighResolutionTime.absolute\(Chronograph\)](#)

absolute(Chronograph, AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime absolute(Chronograph chronograph,  
                                     AbsoluteTime dest)
```

See Section [HighResolutionTime.absolute\(Chronograph, AbsoluteTime\)](#)

relative(Chronograph)

Signature

```
public  
javax.realtime.RelativeTime relative(Chronograph chronograph)
```

See [Section HighResolutionTime.relative\(Chronograph\)](#)

relative(Chronograph, RelativeTime)

Signature

```
public  
    javax.realtime.RelativeTime relative(Chronograph chronograph,  
                                         RelativeTime dest)
```

See [Section HighResolutionTime.relative\(Chronograph, RelativeTime\)](#)

9.5 Rationale

Time is the essence of realtime systems, and a method of expressing absolute time with sub-millisecond precision is an absolute minimum requirement. Expressing time in terms of nanoseconds has precedent and allows the implementation to provide time-based services, such as timers, using whatever precision it is capable of while the application requirements are expressed to an arbitrary level of precision.

The standard Java `java.util.Date` class uses milliseconds as its basic unit in order to provide sufficient range for a wide variety of applications. realtime programming generally requires finer resolution, and nanosecond resolution is fine enough for most purposes, but even a 64 bit realtime clock based in nanoseconds would have insufficient range in some situations, so a compound format composed of 64 bits of millisecond timing, and 32 bits of nanoseconds within a millisecond, was chosen.

The expression of millisecond and nanosecond constituents is consistent with other Java interfaces.

The expression of relative times allows for time-based metaphors such as deadline-based periodic scheduling where the cost of the task is expressed as a relative time and deadlines are usually represented as times relative to the beginning of the period.

Chapter 10

Clocks and Timers

10.1 Overview

In order to reason about time, the RTSJ needs not only to be able to express times and calculate with them; but it also needs to be able to determine the current time and allow actions to be performed when a given time is reached. For this purpose, the specification defines one interface and four classes: `Chronograph`, `Clock`, `Timer`, `PeriodicTimer`, and `OneShotTimer`.

A chronograph is used to measure time, whereas a clock is used to both measure time and react to its passage: a clock can get the current time and it can trigger timing events. At least one instance of the abstract `Clock` class, which implements `Chronograph`, is provided by the implementation, the system *realtime clock*, and this instance is made available as a singleton. The creation and use of other clocks and chronographs are discussed later (see Section 10.3.2).

The `Timer` classes provide the means of executing code at a particular point in time or repeatedly at a given interval. `Timer` is an abstract class and consequently only its subclasses can be instantiated. The `Timer` class provides the interface and underlying implementation for both one-shot and periodic timers. Instances of `OneShotTimer` and `PeriodicTimer` can be created and rescheduled specifying the initial firing time either as an `AbsoluteTime` or as a `RelativeTime`, to be considered from the application of the start command. The `PhasingPolicy` class defines the relationship between a `PeriodicTimer`'s start time and its first release time when the start time is in the past.

By attaching an `AsyncBaseEventHandler` to a `Timer`, the program can cause the release of the handler at a given time or after a given interval. An instance of `OneShotTimer` describes an event that is to be triggered at most once (unless restarted after expiration). It may be used as the source for time-outs and watchdog timing. An instance of `PeriodicTimer` fires on a periodic schedule. The period for

a `PeriodicTimer` is always specified as a `RelativeTime`.

10.2 Definitions

Understanding the support for clocks and timer requires some basic terms.

A *Timing Mechanism* is something capable of representing and following the progress of time, by means of time values.

A *Chronograph* is a passive timing mechanism, which can only provide the current time.

A *Clock* is an active timing mechanism, which can both provide the current time as well as cause some action when a particular time is reached. All clocks are, by definition, chronographs, but not visa verse.

A *Monotonic Timing Mechanism* is a timing mechanism whose time values always progress in one direction, and

A *Monotonically Increasing* timing mechanism is one whose time values never decrease. Monotonicity is a Boolean property, while time synchronization, uniformity, and accuracy are characteristics that depend on agreed tolerances.

Time Synchronization is a relation between two timing mechanisms. Two chronographs are synchronized when the difference between their time values is less than some specified offset. Synchronization in general degrades with time, and may be lost, given a specified offset.

Accuracy is the agreement between a chronograph and the true value that it measures (*e.g.*, absolute wall clock time).

Resolution is the minimal time value interval that can be represented by the clock model.

Precision is the smallest tick size that a particular chronograph will observe.

Uniformity, in this context, refers to the measurement of the progress of time at a consistent rate, with a tolerance on the variability. Uniformity is affected by two other factors, *jitter* and *stability*.

Jitter is caused by short-term and non-cumulative small time variation due to noise sources, such as thermal noise. More practically, jitter refers to the distribution of the differences between when events are actually fired or noticed by the software and when they should have really occurred according to time in the real-world.

Stability in this context refers to temporal stability. Lack of stability accounts for large and often cumulative variations, due to *e.g.* supply voltage and temperature.

Drift is this rate of this cumulative variation between two timing mechanisms.

Epoch An epoch is the date and time relative to which a computer's clock and timestamp values are determined. The epoch traditionally corresponds to 0 hours, 0 minutes, and 0 seconds (00:00:00) Coordinated Universal Time (UTC) on a specific date.

The Epoch is January 1, 1970, 00:00:00 GMT.

Counting Time is the time accumulated by a **Timer**, while *active*, when created or rescheduled using a **RelativeTime** to specify the initial firing/skipping time. *Counting Time* is zeroed at the beginning of an activation, or when rescheduled, while *active*, before the initial firing/skipping of an activation.

10.3 Semantics

The semantics of chronographs, clocks and timers are not simply functional. Temporal attributes dominate their behavior; therefore, the interaction between classes is critical to the overall understanding of the API. The class descriptions as well as their constructor, method, and field documentation given later provide detailed semantics to support the overall behavior.

10.3.1 Clock Model

Clocks and chronographs are backed by a physical means of measuring time. In practice, each one is driven by an oscillator that has susceptible variation due to its environment. There is always some difference between the desired frequency and the actual frequency of the oscillator, which is a major reason of synchronization loss. The RTSJ Clock model must take this variability into account and therefore establishes several invariants and expectations that can be relied upon by RTSJ applications and in turn must be provided by RTSJ implementations.

1. The *resolution* of the RTSJ Clock model is 1 nanosecond. This is the smallest unit of time that can be represented by a chronograph or timer via **HighResolutionTime** and its subclasses.
2. The *accuracy* of RTSJ definable chronographs and clocks is outside the scope of this specification. Accuracy is heavily dependent on hardware capabilities and platform characteristics. RTSJ providers and system integrators should characterize accuracy where possible.
3. The *precision* of RTSJ definable clock and chronograph (and, by proxy, the precision of the timers associated with clocks) are defined in terms of nanoseconds per observable tick, and provided to the application programmer via the various precision setters on **Clock** and **Chronograph**.
4. The realtime clock will be monotonically increasing, and other clocks and chronographs should be monotonically increasing as well.
5. Time values returned by a chronograph should not be assumed to be comparable to the time values from another chronograph unless the user has platform-specific knowledge that the chronographs are compatible, except under specific circumstances described below.

6. The system or any other realtime clock is not necessarily synchronized with the external world, and the correctness of the epoch as a time base depends on such synchronization. It is as uniform and accurate as allowed by the underlying hardware.

If two **Chronograph** objects are both referenced to real time and return a value from `getEpochOffset()`, then time values from those **Chronographs** can be compared by applying their respective corrections. As documented in the `getEpochOffset()` method, its return value represents the offset of the associated **Chronograph** from the realtime clock Epoch. However, the results of any such comparison must be treated with caution as the accuracy of the two **Chronograph** objects may be different.

10.3.2 Clocks and Timables

A **Clock** is the basic mechanism of measuring time and triggering events based on the passage of time. A **Timer** can request a signal from the clock when a given time is reached. That signal should come as closed to the actual time requested as possible. A schedulable also uses a clock to implement the realtime sleep methods. Each clock instance shall be capable of reporting the achievable resolution of timers based on that clock. Each implementation shall have a default clock that is used whenever no other clock is specified. An application can also defined additional clocks.

A **Timer** use a clock to measures time, and informs a **TimeDispatcher** when the time has elapsed (relative time) or has been reached (absolute time). The **TimeDispatcher** causes the release of any **AsyncEventHandler** associated with the **Timer**. In the context of a **Timer**, *triggering* is the action that is performed by a **TimeDispatcher** that informs the **Timer** that it is time to *fire* or *skip*, where skip causes the normal action of fire not to be carried out.

A **Timer** is *active* when it has been started and not stopped since last started and it has a time in the future at which it is expected to fire or skip, else it is *not active*.

In the context of a **Timer**, *enabling* cause the **Timer** to fire when it is triggered, while *disabling* causes the **Timer** to skip when it is triggered. Enabling and disabling act as a mask over firing.

The behavior of a **OneShotTimer** is that of a **Timer** that does not automatically reschedule its triggering after an initial triggering, regardless of whether it fires or skips (when *disabled* and *active* when triggered). It is specified using an initial firing time.

The behavior of a **PeriodicTimer** is that of a **Timer** that automatically reschedules after each triggering, regardless of whether the triggering results in a fire or a

skip due to being disabled when triggered. It is specified using an initial firing time and an interval or period used for the self-rescheduling.

A **Clock** can also be used to regulate pauses in execution of any **Schedulable** through a realtime **sleep** method, hence timers and schedulables are classified as timables under the **Timable** interface.

Both **OneShotTimer** and **PeriodTimer** are given an initial firing time. A **PeriodicTimer** receives two clock references, within two **HighResolutionTimer** objects, which must be to the same clock. Thus the specification of the initial firing time and the interval or period must refer to the same clock.

A **Timer** is an **ActiveEvent**. This means that it has an associated dispatcher called **TimeDispatcher**. As with other active events, the application can either use the default dispatcher or create a new one with its own priority and affinity. A schedulable can also have a **TimeDispatcher** to manage sleeping.

Every timable, **Timer** or **Schedulable**, has one clock associated with it, on which the measurement of time will be based. Each clock maintains a list of times, called alarms, that are provided to it from timables. The clock is armed with the next alarm. When that time arrives, the clock signals the **TimeDispatcher** associated with the alarm to signal its timable that the time has arrived.

In the case of a timer, the dispatcher triggers the timer thereby indicating it should fire or skip. In the case of a schedulable, the dispatcher triggers the schedulable to wake up from its sleep. Figure 10.1 illustrates how a timer interacts with an application-defined clock and Figure 10.2 depicts the same for using realtime sleep in a schedulable.

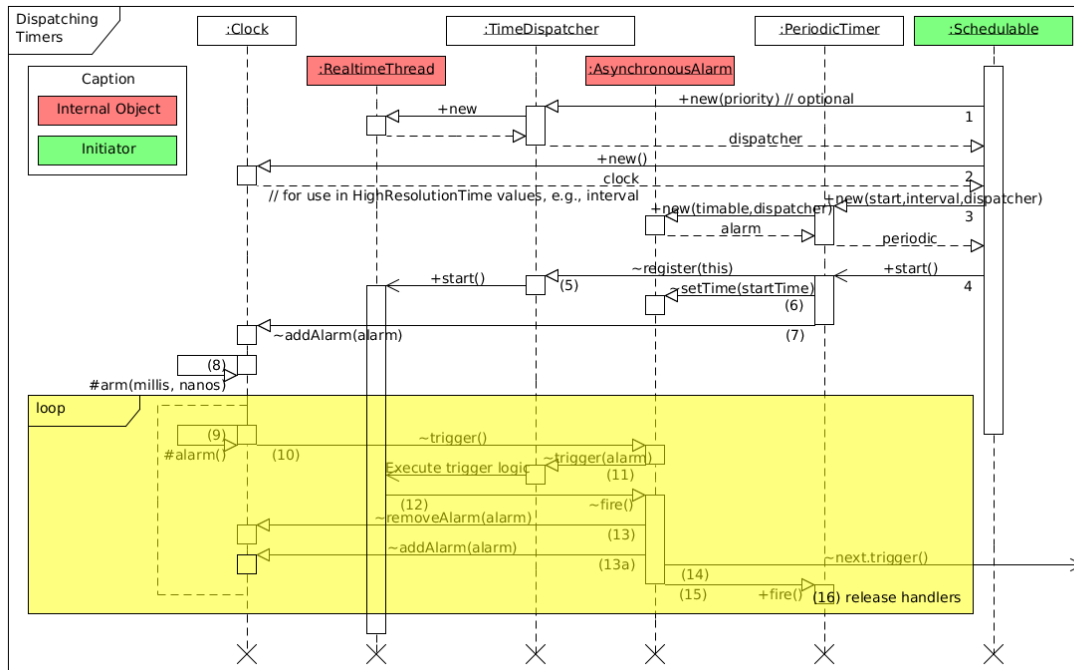
In each case, an external schedulable, depicted on the right, initializes the objects involved. A **TimeDispatcher** and a **Clock** are created. These are used when creating the **Timable** as illustrated with step one and two respectively in both diagrams. A developer can always use a pre-existing clock or dispatcher instead of creating new ones.

Each timable acts as if it had an internal object, depicted as an instance of **Alarm**, to manage the relationship between a timable and its dispatcher and clock. **Alarm** is shown simply to illustrate this relationship. It is created, step three in both diagrams, when the timable is created and it represents the next alarm that the timable should receive: a fire for a time or a wake up call for a realtime sleep on a schedulable.

At step four, the two sequences diverge. The application starts a timer with the **start** method, but a thread must call a realtime sleep method. In both cases, step four sets the timing in motion.

Steps (5) through (8) set up the time interval. For initiating the trigger for the first time, step (5) registers the timable with its dispatcher. Later starts or sleeps skip this step. Then the time is set in the alarm and the alarm is added to the clock.

Figure 10.1: Sequence Diagram for Using a Timer



When the new alarm is the next alarm to be triggered, the clock arranges to signal that time as in step (8). When the alarm is added anywhere else in the clock queue, step (8) is delayed until the removal of an alarm causes the added alarm to reach the top of the queue.

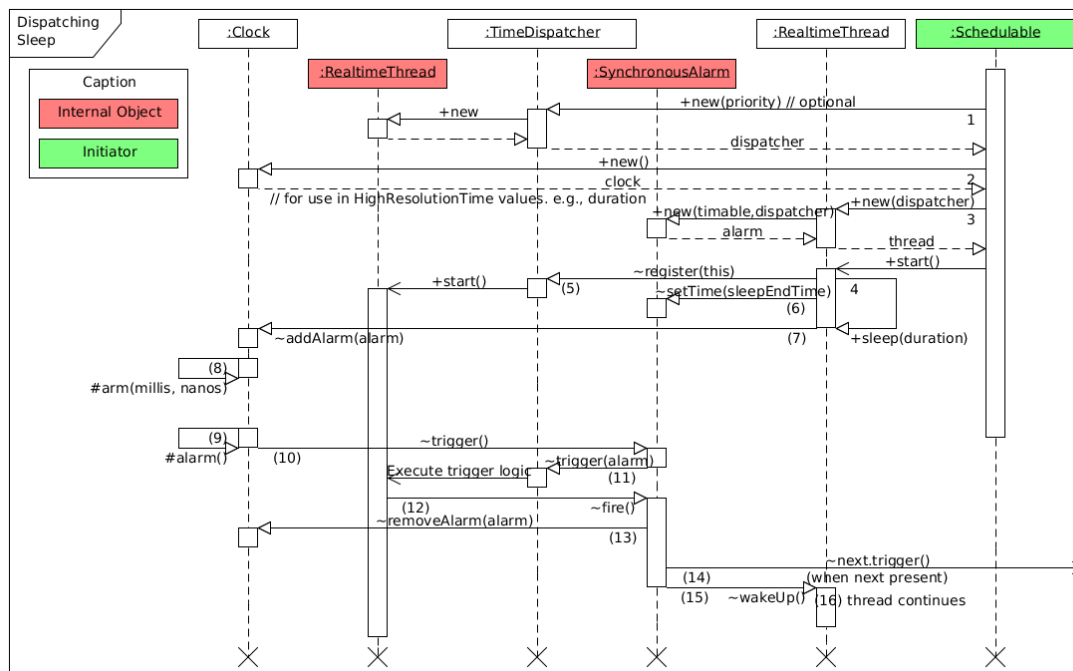
When the alarm time is reached, step (9), the clock triggers the alarm by calling trigger on the alarm event, step (10). This in turn triggers the dispatcher, step (11). This is an asynchronous call that causes the dispatcher's thread to take over control from the clocks interrupt handler.

In step (12), the dispatcher thread removes the alarm from the clock queue, possibly causing a new alarm to become active. In the periodic thread case, the alarm is rescheduled by incrementing the time in the alarm by the interval and adding it back into the queue. In all other cases, no new alarm is set.

In step (13) any subsequent alarms that were scheduled are also kicked off. The Clock queue is a two dimensional queue that is organized by the time of the alarm and, within any given time, the priority order, highest to lowest, of the dispatchers associated with the alarms. The trigger in step (10) always goes to the alarm with the highest priority dispatcher.

Finally in step (14), the dispatcher fires the alarm which results its timable being

Figure 10.2: Sequence Diagram for Realtime Sleep



fired or woken-up. In the case of a timer, this causes all its handlers to be released or, in the case of a schedulable, a sleep being woken up; this is marked as (15) in the diagrams.

Clocks and **TimeDispatchers** may be shared among many as timables as the needs of the application dictate. Different dispatchers can be used with a given clock and a dispatcher can service different clocks. The dispatcher should be chosen based on its priority and affinity, whereas a clock should be chosen based on the temporal reference, where the temporal reference may or may not be associated with clock time. For instance, one could use a clock to represent the rotation of a shaft.

10.3.3 Timers

A timer must be associated with a clock. That clock acts as if it provides an interrupt to each of its timers at the next instance of time at which the timer should do something. In other words, a clock fires its timer at a requested time. Timers can be modeled as counters, or as comparators.

10.3.3.1 Counter Model

In the timer model, a timer can be viewed as if every clock interrupt increments a count up to the firing count, initially given by either an instance of `RelativeTime` or computed as the difference between an instance of `AbsoluteTime` and a semantically specified “now” (using the same clock).

1. `start` is understood as defining “now” and start counting, `stop` is understood as stop counting. `start` after `stop` may be understood as start counting again from where stopped, or start from scratch after resetting the count.
2. In both cases, a delay is introduced.
3. An `RTSJ Timer`, when using the counter model, resets the count when it is restarted after being stopped.
4. When a `Timer` is created or rescheduled using a `RelativeTime` to specify the initial alarm time, the `RTSJ` keeps the specified initial trigger time as a `RelativeTime` and behaves according to the counter model.

10.3.3.2 Comparator Model

In the comparator model, a `Timer` can be viewed as if every clock interrupt forces a comparison between an absolute time and a firing time, initially given either as an instance of `AbsoluteTime` or computed as the sum of an instance of `RelativeTime` and a semantically specified “now” (using the same clock).

1. In this model, `start` is understood as start comparing, and possibly the first `start` is understood as defining “now”. `stop` is understood as stop comparing. `start` after `stop` may be understood as start comparing again.
2. In this case, no delay is introduced.
3. When a `Timer` is created or rescheduled using an `AbsoluteTime` to specify the initial triggering time, the `RTSJ` keeps the specified initial firing time as an `AbsoluteTime` and uses the comparator model.

10.3.3.3 Triggering

A clock signals to the associated timetable that its alarm time has been reached by triggering the dispatcher associated with the timetable. This trigger causes the dispatcher to fire the associated timer. When the timer is active, it releases its handlers and is said to be fired. When the timer is inactive, nothing happens and it is said to be skipped. A stopped timer is never triggered. For this it must be running.

10.3.3.4 Behavior of Timers

There are two kinds of timers defined: `OneShotTimer` and `PeriodicTimer`. As their names imply, the first is used to mark a single time interval and the second is to mark a regularly repeating time interval.

The `OneShotTimer` class shall ensure that each instance is fired at most once at the time specified unless restarted after expiration.

The `PeriodicTimer` class shall enable the period of a timer to be expressed in terms of a `RelativeTime`. The initial firing of a `PeriodicTimer` occurs in response to the invocation of its `start` method, in accordance with the start time passed to its constructor. The `PhasingPolicy` class defines the relationship between the timer's start time and its first firing when the start time is in the past. This initial firing or skipping, may be rescheduled by a call to the `reschedule` method, in accordance with the time passed to that method.

Given an instance of `PeriodicTimer`, let S be the effective time, as an absolute time, at which the initial firing or skipping, of a `PeriodicTimer` is scheduled to occur:

1. when the start, or reschedule, time was given as an absolute time, A , and that time is in the future when the timer is made active, then S equals A , otherwise
2. when the absolute time has passed when the timer is made active, then S depends on the phasing mode of that instance of `PeriodicTimer`.

The firings of a `PeriodicTimer` are scheduled to occur according to $S + nT$, for $n = 0, 1, 2, \dots$ where S is as just specified, and T is the interval of the periodic timer.

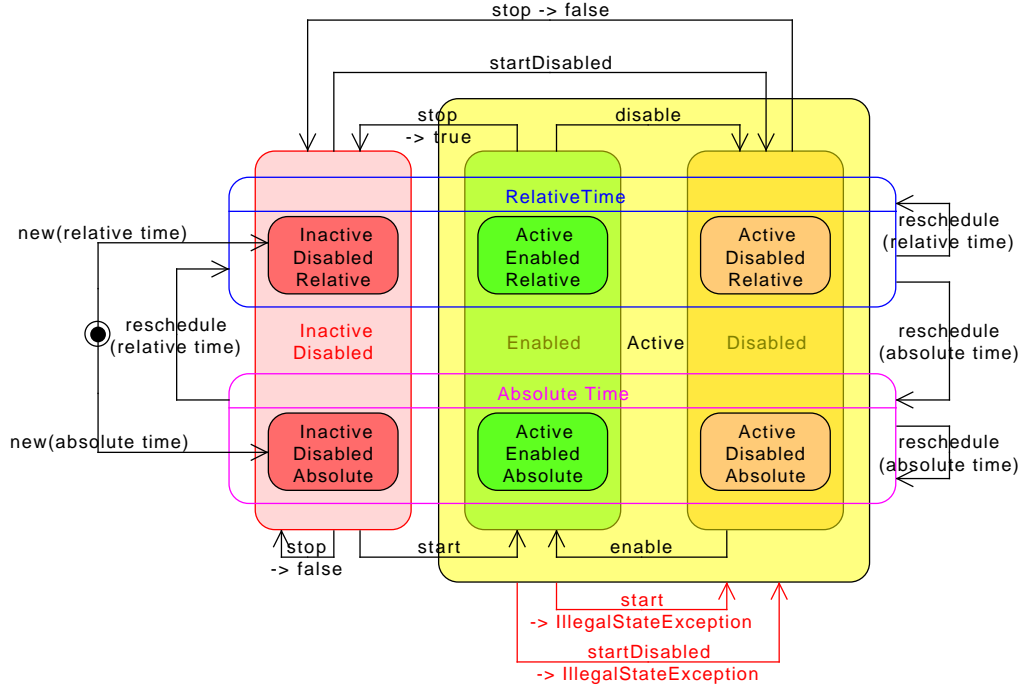
For all timers, when the start or reschedule time is given as a relative time, R , S equals the time at which the *counting time*, started when the timer was made *active*, equals R . The transition to *not-active* by this timer causes the *counting time* to reset, effectively preventing this kind of timer from firing immediately, unless given a time value of 0.

When in a *not-active* state a `Timer` retains the parameters given at construction time or the parameters it had at de-activation time. Those are the parameters that will be used upon invocation of `start` while in that state, unless the parameters are explicitly changed before that, using `reschedule` and `setInterval` as appropriate.

When a `Timer` object is allocated in a scoped memory area, then it will increment the reference count associated with that area. Such a reference count will only be decremented when the `Timer` object is destroyed. (See semantics in the *Memory* chapter for details.) A `Timer` object will not fire before its due time.

The states of a `Timer` are essentially the same as for an `ActiveEvent` as depicted in Figure 8.3. The main difference is that the time used for the next fire may be either an absolute time or a relative time. Figure 10.3 reflects this difference in a UML state diagram.

Figure 10.3: States of a Timer



10.3.3.5 Phasing

Phasing comes into play only when a periodic timer (with period T) starts after its initial time. This can happen when an absolute start time (A) is specified and the start method is called after that time. It is used to determine the effective start time S :

1. S is the next multiple of $A + nT$, when phasing is **ADJUST_FORWARD**,
2. S is the most recent multiple of $A + nT$, when phasing is **ADJUST_BACKWARD**,
3. S is “now,” when phasing is **ADJUST_TO_START**, and
4. S is undefined and an exception is thrown when phasing is **STRICT_PHASING**.

The default phasing is **ADJUST_TO_START**.

10.4 Package javax.realtime

10.4.1 Interfaces

10.4.1.1 AsyncTimable

Interfaces

Timable

A common type for **Timer**¹ and **RealtimeThread**² to indicate that they can be associated with a **Clock**³ and be suspended waiting for time events based on that clock.

10.4.1.1.1 Methods

fire

Signature

```
public  
void fire()
```

Inform the dispatcher associated with this Timable that a time event has occurred.

10.4.1.2 Chronograph

The interface for all devices that support the measurement of time with great accuracy.

10.4.1.2.1 Methods

¹Section 10.4.2.5

²Section 5.3.2.2

³Section 10.4.2.1

getEpochOffset

Signature

```
public  
javax.realtime.RelativeTime getEpochOffset()
```

Returns the relative time of the offset of the epoch of **this** clock from the Epoch of the realtime clock. The value returned may change over time due to clock drift.

Throws

`UnsupportedOperationException` when the clock does not have the concept of date.

Returns

A newly allocated `RelativeTime`⁴ object in the current execution context with the offset past the Epoch for **this** clock. The returned object is associated with **this** clock.

getQueryPrecision

Signature

```
public  
javax.realtime.RelativeTime getQueryPrecision()
```

Gets the precision of the time read, the nominal interval between ticks. It is the same as calling `getQueryPrecision(RelativeTime)`⁵ with `null` as an argument.

Returns

a value representing the read precision.

getQueryPrecision(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getQueryPrecision(RelativeTime dest)
```

Gets the precision of the time read, the nominal interval between ticks.

Parameters

dest return the relative time value in **dest**. When **dest** is `null`, allocate a new `RelativeTime`⁶ instance to hold the returned value.

⁴Section 9.4.1.3

⁵Section 10.4.1.2.1

⁶Section 9.4.1.3

Returns

dest set to values representing the read precision.

getTime*Signature*

```
public  
javax.realtime.AbsoluteTime getTime()
```

Gets the current time in a newly allocated object.

Note: This method will return an absolute time value that represents the clock's notion of an absolute time. For clocks that do not measure calendar time this absolute time may not represent a wall clock time.

Returns

A newly allocated instance of [AbsoluteTime⁷](#) in the current allocation context, representing the current time. The returned object is associated with **this** clock.

getTime(AbsoluteTime)*Signature*

```
public  
javax.realtime.AbsoluteTime getTime(AbsoluteTime dest)
```

Gets the current time in an existing object. The time represented by the given [AbsoluteTime⁸](#) is changed at some time between the invocation of the method and the return of the method. *Note:* This method will return an absolute time value that represents the clock's notion of an absolute time. For clocks that do not measure calendar time this absolute time may not represent a wall clock time.

Parameters

dest The instance of [AbsoluteTime⁹](#) object which will be updated in place. The clock association of the **dest** parameter is ignored. When **dest** is not **null** the returned object is associated with **this** clock. When **dest** is **null**, then nothing happens.

Returns

⁷Section [9.4.1.1](#)

⁸Section [9.4.1.1](#)

⁹Section [9.4.1.1](#)

The instance of [AbsoluteTime](#)¹⁰ passed as parameter, representing the current time, associated with `this` clock, or `null` when `dest` was `null`.

10.4.1.3 Timable

Interfaces

[Releasable](#)

A type for all classes that can use a [Clock](#)¹¹ for timing, either for sleeping or for being released at a given time.

10.4.1.3.1 Methods

getDispatcher

Signature

```
public  
    javax.realtime.TimeDispatcher getDispatcher()
```

Get the dispatcher associated with this Timable.

10.4.2 Classes

10.4.2.1 Clock

Inheritance

```
java.lang.Object  
    javax.realtime.Clock
```

Interfaces

[Chronograph](#)

A clock marks the passing of time. It has a concept of now that can be queried through `Clock.getTime()`, and it can have events queued on it which will be fired when their appointed time is reached.

¹⁰Section [9.4.1.1](#)

¹¹Section [10.4.2.1](#)

Note that while all `Clock` implementations use representations of time derived from `HighResolutionTime`, which expresses its time in milliseconds and nanoseconds, a particular `Clock` may track time that is not delimited in seconds or not related to wall clock time in any particular fashion (*e.g.*, revolutions or event detections). In this case, the `Clock`'s timebase should be mapped to milliseconds and nanoseconds in a manner that is computationally appropriate.

10.4.2.1.1 Constructors

Clock

Signature

```
public  
Clock()
```

Constructor for the abstract class.

10.4.2.1.2 Methods

getRealtimeClock

Signature

```
public static  
javax.realtime.Clock getRealtimeClock()
```

There is always at least one clock object available: the system realtime clock. This is the default `Clock`.

Returns

The singleton instance of the default `Clock`

getEpochOffset

Signature

```
public final
  javax.realtime.RelativeTime getEpochOffset()
  throws UnsupportedOperationException
```

Returns the relative time of the offset of the epoch of **this** clock from the Epoch of the realtime clock.

Throws

`UnsupportedOperationException` when the clock does not have the concept of date.

Returns

A newly allocated `RelativeTime`¹² object with the offset past the Epoch for **this** clock. The returned object is associated with **this** clock.

getDrivePrecision

Signature

```
public abstract
  javax.realtime.RelativeTime getDrivePrecision()
```

Gets the precision of the clock for driving events, the nominal interval between ticks that can trigger an event. It is the same as calling `getDrivePrecision(RelativeTime)`¹³ with `null` as its argument.

Returns

a value representing the drive precision.

getDrivePrecision(RelativeTime)

Signature

```
public abstract
  javax.realtime.RelativeTime getDrivePrecision(RelativeTime dest)
```

Gets the precision of the clock for driving events, the nominal interval between ticks that can trigger an event. The result may be larger than that of `getQueryPrecision(RelativeTime)`¹⁴.

Parameters

¹²Section 9.4.1.3

¹³Section 10.4.2.1.2

¹⁴Section 10.4.2.1.2

dest return the relative time value in **dest**. When **dest** is **null**, it allocates a new [RelativeTime](#)¹⁵ instance to hold the returned value.

Returns

dest set to values representing the drive precision.

getQueryPrecision

Signature

```
public abstract  
java.xml.realtime.RelativeTime getQueryPrecision()
```

Gets the precision of the time read, the nominal interval between ticks. It is the same as calling [getQueryPrecision\(RelativeTime\)](#)¹⁶ with **null** as an argument.

Returns

the value representing the read precision.

getQueryPrecision(RelativeTime)

Signature

```
public abstract  
java.xml.realtime.RelativeTime getQueryPrecision(RelativeTime dest)
```

Gets the precision of the time read, the nominal interval between ticks. The result may be smaller than that of [getDrivePrecision\(RelativeTime\)](#)¹⁷, when the clock is tied to some system tick for releasing events.

Parameters

dest return the relative time value in **dest**. When **dest** is **null**, allocate a new [RelativeTime](#)¹⁸ instance to hold the returned value.

Returns

dest set to values representing the read precision.

getTime

Signature

¹⁵Section [9.4.1.3](#)

¹⁶Section [10.4.2.1.2](#)

¹⁷Section [10.4.2.1.2](#)

¹⁸Section [9.4.1.3](#)

```
public final
    javax.realtime.AbsoluteTime getTime()
```

Gets the current time in a newly allocated object.

Note: This method will return an absolute time value that represents the clock's notion of an absolute time. For clocks that do not measure calendar time this absolute time may not represent a wall clock time.

Returns

A newly allocated instance of [AbsoluteTime](#)¹⁹ representing the current time. The returned object is associated with **this** clock.

getTime(AbsoluteTime)

Signature

```
public abstract
    javax.realtime.AbsoluteTime getTime(AbsoluteTime dest)
```

Gets the current time in an existing object. The time represented by the given [AbsoluteTime](#)²⁰ is changed at some time between the invocation of the method and the return of the method. *Note:* This method will return an absolute time value that represents the clock's notion of an absolute time. For clocks that do not measure calendar time this absolute time may not represent a wall clock time.

Parameters

dest The instance of [AbsoluteTime](#)²¹ object which will be updated in place. The clock association of the **dest** parameter is set to **this**. When **dest** is not **null** the returned object is associated with **this** clock. When **dest** is **null**, a new object is allocated.

Returns

The instance of [AbsoluteTime](#)²² passed as parameter, representing the current time, associated with **this** clock, or **null** when **dest** was **null**.

setResolution(RelativeTime)

Signature

¹⁹Section [9.4.1.1](#)

²⁰Section [9.4.1.1](#)

²¹Section [9.4.1.1](#)

²²Section [9.4.1.1](#)

```
public abstract
void setResolution(RelativeTime resolution)
```

Set the resolution of **this**. For some hardware clocks setting resolution is impossible and when this method is called on those clocks, then an `UnsupportedOperationException` is thrown.

Parameters

resolution The new resolution of **this**, when the requested value is supported by **this** clock. When **resolution** is smaller than the minimum resolution supported by **this** clock then it throws `IllegalArgumentException`. When the requested **resolution** is not available and it is larger than the minimum resolution, then the clock will be set to the closest resolution that the clock supports, via truncation. The value of the **resolution** parameter is not altered. The clock association of the **resolution** parameter is ignored.

Throws

`IllegalArgumentException` when **resolution** is `null`, or when the requested **resolution** is smaller than the minimum resolution supported by this clock.

`UnsupportedOperationException` when the clock does not support setting its resolution.

triggerAlarm

Signature

```
protected final
void triggerAlarm()
```

Code in the abstract base `Clock` is called by a subclass to signal that the time of the next alarm has been reached. It will trigger a `TimeDispatcher`²³, which in turn will cause a fire on an associated `AsyncTimable`²⁴

setAlarm(long, int)

Signature

```
protected abstract
void setAlarm(long milliseconds,
               int nanoseconds)
```

²³Section 10.4.2.4

²⁴Section 10.4.1.1

Implemented by subclasses to set the time for the next alarm. When there is an alarm outstanding when called, the subclass must override the old time. This should never be called from application or library code. It is intended to be called only from the `javax.realtime` package.

Parameters

`milliseconds` of the next alarm.

`nanoseconds` of the next alarm.

clearAlarm

Signature

```
protected abstract
void clearAlarm()
```

Implemented by subclasses to cancel the current outstanding alarm.

10.4.2.2 OneShotTimer

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncEvent
      javax.realtime.Timer
        javax.realtime.OneShotTimer
```

A timed [AsyncEvent](#)²⁵ that is driven by a [Clock](#)²⁶. It will fire once, when the clock time reaches the time-out time, unless restarted after expiration. When the timer is *disabled* at the expiration of the indicated time, the firing is lost (*skipped*). After expiration, the `OneShotTimer` becomes *not-active* and *disabled*. When the clock time has already passed the time-out time, it will fire immediately after it is started or after it is rescheduled while *active*.

Semantics details are described in the [Timer](#)²⁷ pseudocode and compact graphic representation of state transitions.

10.4.2.2.1 Constructors

²⁵Section [8.4.3.4](#)

²⁶Section [10.4.2.1](#)

²⁷Section [10.4.2.5](#)

OneShotTimer(HighResolutionTime, AsyncEventHandler, TimeDispatcher)

Signature

```
public
OneShotTimer(javax.realtime.HighResolutionTime<?> time,
              AsyncEventHandler handler,
              TimeDispatcher dispatcher)
throws IllegalArgumentException,
      UnsupportedOperationException,
      IllegalAssignmentError
```

Create an instance of [OneShotTimer](#)²⁸, based on the [Clock](#)²⁹ associated with the `time` parameter, that will execute its `fire` method according to the given time.

Parameters

`time` The time used to determine when to fire the event. A `time` value of `null` is equivalent to a `RelativeTime` of 0, and in this case the `Timer` fires immediately upon a call to `start()`.

`handler` The [AsyncEventHandler](#)³⁰ that will be released when `fire` is invoked. When `null`, no handler is associated with this `Timer` and nothing will happen when this event fires unless a handler is subsequently associated with the timer using the `addHandler()` or `setHandler()` method.

`dispatcher` The [TimeDispatcher](#)³¹ to use for triggering this event.

Throws

`IllegalArgumentException` when `time` is a `RelativeTime` instance less than zero.

`UnsupportedOperationException` when the [Chronograph](#)³² associated with `time` is not a [Clock](#)³³.

`IllegalAssignmentError` when this `OneShotTimer` cannot hold a reference to `handler`.

OneShotTimer(HighResolutionTime, AsyncEventHandler)

²⁸Section [10.4.2.2](#)

²⁹Section [10.4.2.1](#)

³⁰Section [8.4.3.5](#)

³¹Section [10.4.2.4](#)

³²Section [10.4.1.2](#)

³³Section [10.4.2.1](#)

Signature

```
public
OneShotTimer(javax.realtime.HighResolutionTime<?> time,
              AsyncEventHandler handler)
```

The equivalent of calling `OneShotTimer(HighResolutionTime, AsyncEventHandler, TimeDispatcher)`³⁴ with arguments `time`, `handler`, `null`.

Parameters

`time` is the time to release its handlers.
`handler` is the hanndler to release.

10.4.2.3 PeriodicTimer**Inheritance**

```
java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncEvent
      javax.realtime.Timer
        javax.realtime.PeriodicTimer
```

An `AsyncEvent`³⁵ whose `fire` method is executed periodically according to the given parameters. The clock associated with the `Timer` start time must be identical to the the clock associated with the `Timer` `interval`

The first firing is at the beginning of the first interval.

When an interval greater than 0 is given, the timer will fire periodically. When an interval of 0 is given, the `PeriodicTimer` will only fire once, unless restarted after expiration, behaving like a `OneShotTimer`. In all cases, when the timer is *disabled* when the firing time is reached, that particular firing is lost (*skipped*). When *enabled* at a later time, it will fire at its next scheduled time.

When the clock time has already passed the beginning of the first period, the `PeriodicTimer` will first fire according to the `PhasingPolicy`³⁶.

Semantics details are described in the `Timer`³⁷ pseudo-code and compact graphic representation of state transitions.

³⁴Section 10.4.2.2.1

³⁵Section 8.4.3.4

³⁶Section 5.3.1.1

³⁷Section 10.4.2.5

10.4.2.3.1 Constructors

PeriodicTimer(HighResolutionTime, RelativeTime, AsyncEventHandler)

Signature

```
public
PeriodicTimer(javax.realtime.HighResolutionTime<?> start,
               RelativeTime interval,
               AsyncEventHandler handler)
throws IllegalArgumentException,
       IllegalAssignmentError
```

Create a timer that executes its fire method periodically. Equivalent to `PeriodicTimer(start, interval, handler, null)`.

PeriodicTimer(HighResolutionTime, RelativeTime, AsyncEventHandler, TimeDispatcher)

Signature

```
public
PeriodicTimer(javax.realtime.HighResolutionTime<?> start,
               RelativeTime interval,
               AsyncEventHandler handler,
               TimeDispatcher dispatcher)
throws IllegalArgumentException,
       IllegalAssignmentError,
       UnsupportedOperationException
```

Create a timer that executes its fire method periodically.

Parameters

start The time that specifies when the first interval begins, based on the clock associated with it. The first firing of the timer is modified according the `PhasingPolicy` when the timer is started. A **start** value of `null` is equivalent to a `RelativeTime` of 0.

interval The period of the timer. Its usage is based on the clock specified by the **clock** parameter. When **interval** is zero or **null**, the period is ignored and the firing behavior of the **PeriodicTimer** is that of a **OneShotTimer**³⁸.

handler The **AsyncEventHandler**³⁹ that will be released when **fire** is invoked. When **null**, no handler is associated with this **Timer** and nothing will happen when this event fires unless a handler is subsequently associated with the timer using the **addHandler()** or **setHandler()** method.

dispatcher is the dispatcher to use for triggering this event.

Throws

IllegalArgumentException when **start** or **interval** is a **RelativeTime** instance with a value less than zero; or the clocks associated with **start** and **interval** are not the identical.

IllegalAssignmentError when this **PeriodicTimer** cannot hold references to **handler**, **clock** and **interval**.

UnsupportedOperationException when the **Chronograph**⁴⁰ associated with **time** is not a **Clock**⁴¹.

10.4.2.3.2 Methods

addHandler(AsyncEventHandler)

Signature

```
public
void addHandler(AsyncEventHandler handler)
throws IllegalArgumentException,
       IllegalAssignmentError
```

Add a handler to the set of handlers associated with this event. It overrides the method in **AsyncBaseEvent**⁴² to allow the use of handlers with **PeriodicParameters**⁴³, but these parameters must match the period of this timer, otherwise **IllegalArgumentException** is thrown.

Parameters

³⁸Section 10.4.2.2

³⁹Section 8.4.3.5

⁴⁰Section 10.4.1.2

⁴¹Section 10.4.2.1

⁴²Section 8.4.3.2

⁴³Section 6.4.2.5

`handler` a new handler to add to the list of handlers already associated with `this`. When `handler` is already associated with the event, the call has no effect.

Throws

`IllegalArgumentException` when `handler` is null or the handler has `PeriodicParameters`⁴⁴ with a period that does not match the period of `this`.

`IllegalAssignmentError` when this `AsyncEvent` cannot hold a reference to `handler`.

setHandler(AsyncEventHandler)

Signature

```
public
void setHandler(AsyncEventHandler handler)
throws IllegalArgumentException,
    IllegalAssignmentError
```

Associate a new handler with this event and remove all existing handlers. It overrides the method in `AsyncBaseEvent`⁴⁵ to allow the use of handlers with `PeriodicParameters`⁴⁶, but these parameters must match the period of this timer, otherwise `IllegalArgumentException` is thrown.

Parameters

`handler` The instance of `AsyncBaseEventHandler`⁴⁷ to be associated with `this`. When `handler` is null, no handler will be associated with `this`, i.e., behave effectively as when `setHandler(null)` invokes `removeHandler(AsyncBaseEventHandler)` for each associated handler.

Throws

`IllegalArgumentException` when `handler` has `PeriodicParameters`⁴⁸ with a period that does not match the period of `this`.

`IllegalAssignmentError` when this `AsyncEvent` cannot hold a reference to `handler`.

start(PhasingPolicy)

Signature

⁴⁴Section 6.4.2.5

⁴⁵Section 8.4.3.2

⁴⁶Section 6.4.2.5

⁴⁷Section 8.4.3.3

⁴⁸Section 6.4.2.5

```
public
void start(PhasingPolicy phasingPolicy)
throws LateStartException,
        IllegalArgumentException
```

Start the timer with the specified [PhasingPolicy](#)⁴⁹.

Parameters

`phasingPolicy` determines what happens when the start is too late.

Throws

`LateStartException` when this method is called after its absolute start time and the `phasingPolicy` is [PhasingPolicy.STRICT_PHASING](#)⁵⁰.

`IllegalArgumentException` when the start time of this timer is not an absolute time, or `phasingPolicy` is null.

start(boolean, PhasingPolicy)

Signature

```
public
void start(boolean disabled,
           PhasingPolicy phasingPolicy)
throws LateStartException,
        IllegalArgumentException
```

Start the timer with the specified [PhasingPolicy](#)⁵¹ and the specified disabled state.

Parameters

`disabled` determine the mode of start: `true` for enabled and `false` for disabled for consistency with [Timer.start\(boolean\)](#)⁵².

`phasingPolicy` determines what happens when the start is too late.

Throws

`LateStartException` when this method is called after its absolute start time and the `phasingPolicy` is [PhasingPolicy.STRICT_PHASING](#)⁵³.

`IllegalArgumentException` when the start time of this timer is not an absolute time, or `phasingPolicy` is null.

⁴⁹Section [5.3.1.1](#)

⁵⁰Section [5.3.1.1.1](#)

⁵¹Section [5.3.1.1](#)

⁵²Section [10.4.2.5.4](#)

⁵³Section [5.3.1.1.1](#)

getClock

Signature

```
public  
java.xml.realtime.Clock getClock()  
throws IllegalStateException
```

Each instance can only be associated with a single clock, which this method can obtain.

Throws

`IllegalStateException` when `this` has been destroyed.

Returns

the instance of `Clock`⁵⁴ that is associated with `this`.

createReleaseParameters

Signature

```
public  
java.xml.realtime.ReleaseParameters createReleaseParameters()
```

Create a release parameters object with new objects containing copies of the values corresponding to this timer. When the `PeriodicTimer` interval is greater than 0, create a `PeriodicParameters`⁵⁵ object with a start time and period that correspond to the next firing (or skipping) time, and interval, of this timer. When the interval is 0, create an `AperiodicParameters`⁵⁶ object, since in this case the timer behaves like a `OneShotTimer`⁵⁷.

When this timer is active, then the start time is the next firing (or skipping) time returned as an `AbsoluteTime`⁵⁸. Otherwise, the start time is the initial firing (or skipping) time, as set by the last call to `Timer.reschedule`⁵⁹, or when there was no such call, by the constructor of this timer.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

⁵⁴Section 10.4.2.1

⁵⁵Section 6.4.2.5

⁵⁶Section 6.4.2.2

⁵⁷Section 10.4.2.2

⁵⁸Section 9.4.1.1

⁵⁹Section 10.4.2.5.4

A new release parameters object with new objects containing copies of the values corresponding to this timer. When the interval is greater than zero, return a new instance of [PeriodicParameters](#)⁶⁰. When the interval is zero return a new instance of [AperiodicParameters](#)⁶¹.

getFireTime

Signature

```
public  
javax.realtime.AbsoluteTime getFireTime()  
throws ArithmeticException,  
        IllegalStateException
```

Get the time at which this `PeriodicTimer` is next expected to fire or to skip. When the `PeriodicTimer` is *disabled*, the returned time is that of the skipping of the firing. When the `PeriodicTimer` is *not-active* it throws `IllegalStateException`.

Throws

`ArithmeticException` when the result does not fit in the normalized format.
`IllegalStateException` when this `Timer` has been *destroyed*, or when it is *not-active*.

Returns

The absolute time at which `this` is next expected to fire or to skip, in a newly allocated [AbsoluteTime](#)⁶² object. When the timer has been created or re-scheduled (see [Timer.reschedule\(HighResolutionTime\)](#)⁶³) using an instance of `RelativeTime` for its time parameter then it will return the sum of the current time and the `RelativeTime` remaining time before the timer is expected to fire/skip. Within a periodic timer activation, the returned time is associated with the start clock before the first fire (or skip) time, and associated with the interval clock otherwise.

getFireTime(AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime getFireTime(AbsoluteTime dest)
```

⁶⁰Section [6.4.2.5](#)

⁶¹Section [6.4.2.2](#)

⁶²Section [9.4.1.1](#)

⁶³Section [10.4.2.5.4](#)

Get the time at which this `PeriodicTimer` is next expected to fire or to skip. When the `PeriodicTimer` is *disabled*, the returned time is that of the skipping of the firing. When the `PeriodicTimer` is *not-active* it throws `IllegalStateException`.

Parameters

dest The instance of `AbsoluteTime`⁶⁴ which will be updated in place and returned. The clock association of the **dest** parameter is ignored. When **dest** is `null` a new object is allocated for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.
`IllegalStateException` when this `Timer` has been *destroyed*, or when it is *not-active*.

Returns

The instance of `AbsoluteTime`⁶⁵ passed as parameter, with time values representing the absolute time at which **this** is expected to fire or to skip. When the **dest** parameter is `null` the result is returned in a newly allocated object. When the timer has been created or re-scheduled (see `Timer.reschedule(HighResolutionTime)` using an instance of `RelativeTime` for its time parameter then it will return the sum of the current time and the `RelativeTime` remaining time before the timer is expected to fire/skip. Within a periodic timer activation, the returned time is associated with the start clock before the first fire (or skip) time, and associated with the interval clock otherwise.

getInterval

Signature

```
public  
java.xml.realtime.RelativeTime getInterval()
```

Gets the interval of **this** `Timer`.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

The `RelativeTime` instance assigned as this periodic timer's interval by the constructor or `setInterval(RelativeTime)`⁶⁷.

⁶⁴Section 9.4.1.1

⁶⁵Section 9.4.1.1

⁶⁶Section 10.4.2.5.4

⁶⁷Section 10.4.2.3.2

setInterval(RelativeTime)

Signature

```
public  
void setInterval(RelativeTime interval)
```

Reset the interval value of this.

Parameters

interval A [RelativeTime](#)⁶⁸ object which is the interval used to reset this Timer. A null **interval** is interpreted as `RelativeTime(0,0)`.

The **interval** does not affect the first firing (or skipping) of a timer's activation. At each firing (or skipping), the next fire (or skip) time of an *active* periodic timer is established based on the **interval** currently in use. Resetting the **interval** of an *active* periodic timer only effects future fire (or skip) times after the next.

Throws

`IllegalArgumentException` when **interval** is a `RelativeTime` instance with a value less than zero, or the clock associated with **interval** is different to the clock associated with **this**.

`IllegalAssignmentError` when this `PeriodicTimer` cannot hold a reference to **interval**.

`IllegalStateException` when this `Timer` has been *destroyed*.

10.4.2.4 TimeDispatcher

Inheritance

```
java.lang.Object  
  javax.realtime.ActiveEventDispatcher  
    javax.realtime.TimeDispatcher
```

A dispatcher for time events: [Timer](#)⁶⁹ and [RealtimeThread.sleep](#)⁷⁰.

10.4.2.4.1 Constructors

⁶⁸Section [9.4.1.3](#)

⁶⁹Section [10.4.2.5](#)

⁷⁰Section [5.3.2.2.2](#)

TimeDispatcher(SchedulingParameters)

Signature

```
public  
TimeDispatcher(SchedulingParameters schedule)
```

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`schedule` give the parameters for scheduling this dispatcher

10.4.2.4.2 Methods

register(Timable)

Signature

```
public  
void register(Timable target)  
throws RegistrationException,  
        IllegalStateException,  
        IllegalArgumentException
```

Register a [AsyncTimable](#)⁷¹ with this dispatcher.

Parameters

`target` to register

Throws

`RegistrationException` when `target` is already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `target` is not stopped.

unregister(Timable)

Signature

⁷¹Section [10.4.1.1](#)

```
public
void unregister(Timable target)
throws DeregistrationException,
       IllegalStateException,
       IllegalArgumentException
```

Deregister a [AsyncTimable](#)⁷² from this dispatcher.

Parameters

target to deregister

Throws

DeregistrationException when **target** is not already registered.

IllegalStateException when this object has been destroyed.

IllegalArgumentException when **target** is not stopped.

destroy

Signature

```
public
void destroy()
throws IllegalStateException
```

Release all resources thereby making the dispatcher unusable.

Throws

IllegalStateException when called on a dispatcher that has one or more registered [AsyncTimable](#)⁷³ objects.

10.4.2.5 Timer

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncEvent
      javax.realtime.Timer
```

Interfaces

```
AsyncTimable
ActiveEvent
```

⁷²Section [10.4.1.1](#)

⁷³Section [10.4.1.1](#)

A *timer* is a timed event that measures time according to a given `Clock`⁷⁴. This class defines basic functionality available to all timers. Applications will generally use either `PeriodicTimer`⁷⁵ to create an event that is fired repeatedly at regular intervals, or `OneShotTimer`⁷⁶ for an event that just fires once at a specific time. A timer is always associated with at least one `Clock`⁷⁷, which provides the basic facilities of something that ticks along following some time line (realtime, CPU-time, user-time, simulation-time, etc.). All timers are created *disabled* and do nothing until `start()` is called.

10.4.2.5.1 Pseudo-Code Representation of State Transitions for Timer

An implementation shall behave effectively as if it implemented the following pseudo-code. Only absolute and relative time behaviors are shown as rational time has been deprecated.

NOTE: The pseudo-code does not take into account any issue of synchronization, it just shows the functionality, and the intended behavior is obtained with groups of and'ed statements interpreted as atomic. This is relevant, for example, in cases where the *firing* of an `AsyncEventHandler`⁷⁸ is part of the statements preceding a state transition. While the *firing* causes the release of the handler before the state transition, the execution of the handler does not take place until after the state transition has completed.

The pseudo-code is a model, it should be interpreted as running continuously, with instructions that take no time.

absolute construction state is {**not-active**, **disabled**, **absolute**}

with `nextTargetTime = absoluteTime`

`last_rescheduled_with_AbsoluteTime = TRUE`

[(if `PeriodicTimer`) `period = interval`]

relative construction state is {**not-active**, **disabled**, **relative**}

with `nextDurationTime = relativeTime`

`last_rescheduled_with_AbsoluteTime = FALSE`

[(if `PeriodicTimer`) `period = interval`]

{**not-active**, **disabled**, **absolute**}

[(if `PeriodicTimer`)

set `released_or_skipped_in_current_activation = FALSE`]

⁷⁴Section 10.4.2.1

⁷⁵Section 10.4.2.3

⁷⁶Section 10.4.2.2

⁷⁷Section 10.4.2.1

⁷⁸Section 8.4.3.5

```

enable -> no state change, do nothing
disable -> no state change, do nothing
stop -> no state change, return FALSE
start ->
    [if last_rescheduled_with_AbsoluteTime
    then
        [set targetTime = nextTargetTime
        [if targetTime < currentTime
        then set targetTime = currentTime]
        then go to state {active, enabled, absolute}]
    else
        [set countingTime = 0
        and set durationTime = nextDurationTime
        then go to state {active, enabled, relative}]
isRunning -> return FALSE
reschedule ->
    [if using an instance of AbsoluteTime
    then
        [reset the nextTargetTime to absoluteTime arg
        and set last_rescheduled_with_AbsoluteTime = TRUE
        and no state change]
    else
        [reset the nextDurationTime to relativeTime arg
        and set last_rescheduled_with_AbsoluteTime = FALSE
        and go to state {not-active, disabled, relative}]
getFireTime -> throws IllegalStateException
destroy -> go to state {destroyed}
startDisabled ->
    [if last_rescheduled_with_AbsoluteTime
    then
        [set targetTime = nextTargetTime
        [if targetTime < currentTime
        then set targetTime = currentTime]
        then go to state {active, disabled, absolute}]
    else
        [set countingTime = 0
        and set durationTime = nextDurationTime
        then go to state {active, disabled, relative}]

{not-active, disabled, relative}

```

```

[(if PeriodicTimer)
  set released_or_skipped_in_current_activation = FALSE]
enable -> no state change, do nothing
disable -> no state change, do nothing
stop -> no state change, return FALSE
start ->
  [if last_rescheduled_with_AbsoluteTime
    then
      [set targetTime = nextTargetTime
        [if targetTime < currentTime
          then set targetTime = currentTime]
        then go to state {active, enabled, absolute}]
    else
      [set countingTime = 0
        and set durationTime = nextDurationTime
        then go to state {active, enabled, relative}]]
isRunning -> return FALSE
reschedule ->
  [if using an instance of AbsoluteTime
    then
      [reset the nextTargetTime to absoluteTime arg
        and set last_rescheduled_with_AbsoluteTime = TRUE
        and go to state {not-active, disabled, absolute}]
    else
      [reset the nextDurationTime to relativeTime arg
        and set last_rescheduled_with_AbsoluteTime = FALSE
        and no state change]]
getFireTime -> throws IllegalStateException
destroy -> go to state {destroyed}
startDisabled ->
  [if last_rescheduled_with_AbsoluteTime
    then
      [set targetTime = nextTargetTime
        [if targetTime < currentTime
          then set targetTime = currentTime]
        then go to state {active, disabled, absolute}]
    else
      [set countingTime = 0
        and set durationTime = nextDurationTime
        then go to state {active, disabled, relative}]]

```

```

{active, enabled, absolute}
  [if currentTime >= targetTime
    then
      [if PeriodicTimer
        then
          [if period > 0
            then
              [fire
                and set released_or_skipped_in_current_activation = TRUE
                and self reschedule
                  via targetTime = (targetTime + period)
                and re-enter current state]
            else
              [fire
                and go to state {not-active, disabled, absolute}]]
          else
            [it is a OneShotTimer so
              fire
              and go to state {not-active, disabled, absolute}]]]
  enable -> no state change, do nothing
  disable -> go to state {active, disabled, absolute}
  stop -> [go to state {not-active, disabled, absolute}
    and return TRUE]
  start -> throws IllegalStateException
  isRunning -> return TRUE
  reschedule ->
    [if NOT released_or_skipped_in_current_activation
      then
        [if using an instance of AbsoluteTime
          then
            [reset the targetTime to absoluteTime arg
              and re-enter current state]
          else
            [reset the durationTime to relativeTime arg
              and set countingTime = 0
              and go to state {active, enabled, relative}]]
        else
          [if using an instance of AbsoluteTime
            then

```

```

        [reset the nextTargetTime to absoluteTime arg
         and set last_rescheduled_with_AbsoluteTime = TRUE
         and no state change]
    else
        [reset the nextDurationTime to relativeTime arg
         and set last_rescheduled_with_AbsoluteTime = FALSE
         and no state change]]]
getFireTime -> return targetTime
destroy -> go to state {destroyed}
startDisabled -> throws IllegalStateException

```

{active, enabled, relative}

```

    [if countingTime >= durationTime
     then
        [if PeriodicTimer
         then
            [if period > 0
             then
                [fire
                 and set released_or_skipped_in_current_activation = TRUE
                 and self reschedule
                  via durationTime = (durationTime + period)
                 and re-enter current state]
             else
                [fire
                 and go to state {not-active, disabled, relative}]]
         else
            [it is a OneShotTimer so
             fire
             and go to state {not-active, disabled, relative}]]]
    enable -> no state change, do nothing
    disable -> go to state {active, disabled, relative}
    stop -> [go to state {not-active, disabled, relative}
            and return TRUE]
    start -> throws IllegalStateException
    isRunning -> return TRUE
    reschedule ->
        [if NOT released_or_skipped_in_current_activation
         then
            [if using an instance of AbsoluteTime

```

```

    then
        [reset the targetTime to absoluteTime arg
         and go to state {active, enabled, absolute}]
    else
        [reset the durationTime to relativeTime arg
         and set countingTime = 0
         and re-enter current state]]
else
    [if using an instance of AbsoluteTime
     then
        [reset the nextTargetTime to absoluteTime arg
         and set last_rescheduled_with_AbsoluteTime = TRUE
         and no state change]
     else
        [reset the nextDurationTime to relativeTime arg
         and set last_rescheduled_with_AbsoluteTime = FALSE
         and no state change]]]
getFireTime ->
    return (currentTime + durationTime - countingTime)
destroy -> go to state {destroyed}
startDisabled -> throws IllegalStateException

{active, disabled, absolute}
    [if currentTime >= targetTime
     then
        [if PeriodicTimer
         then
            [if period > 0
             then
                [skip
                 and set released_or_skipped_in_current_activation = TRUE
                 and self reschedule
                 via targetTime = (targetTime + period)
                 and re-enter current state]
             else
                [skip
                 and go to state {not-active, disabled, absolute}]]
         else
            [it is a OneShotTimer so
             skip

```

```

        and go to state {not-active, disabled, absolute}]]]
enable -> go to state {active, enabled, absolute}
disable -> no state change, do nothing
stop -> [go to state {not-active, disabled, absolute}
        and return TRUE]
start -> throws IllegalStateException
isRunning -> return FALSE
reschedule ->
    [if NOT released_or_skipped_in_current_activation
    then
        [if using an instance of AbsoluteTime
        then
            [reset the targetTime to absoluteTime arg
            and re-enter current state]
        else
            [reset the durationTime to relativeTime arg
            and set countingTime = 0
            and go to state {active, disabled, relative}]
    else
        [if using an instance of AbsoluteTime
        then
            [reset the nextTargetTime to absoluteTime arg
            and set last_rescheduled_with_AbsoluteTime = TRUE
            and no state change]
        else
            [reset the nextDurationTime to relativeTime arg
            and set last_rescheduled_with_AbsoluteTime = FALSE
            and no state change]]]
getFireTime -> return targetTime
destroy -> go to state {destroyed}
startDisabled -> throws IllegalStateException

{active, disabled, relative}
    [if countingTime >= durationTime
    then
        [if PeriodicTimer
        then
            [if period > 0
            then
                [skip

```

```

        and set released_or_skipped_in_current_activation = TRUE
        and self reschedule
            via durationTime = (durationTime + period)
        and re-enter current state]
    else
        [skip
            and go to state {not-active, disabled, relative}]]
    else
        [it is a OneShotTimer so
            skip
            and go to state {not-active, disabled, relative}]]
    enable -> go to state {active, enabled, relative}
    disable -> no state change, do nothing
    stop -> [go to state {not-active, disabled, relative}
            and return TRUE]
    start -> throws IllegalStateException
    isRunning -> return FALSE
    reschedule ->
        [if NOT released_or_skipped_in_current_activation
            then
                [if using an instance of AbsoluteTime
                    then
                        [reset the targetTime to absoluteTime arg
                            and go to state {active, disabled, absolute}]]
                else
                    [reset the durationTime to relativeTime arg
                        and set countingTime = 0
                        and re-enter current state]]
            else
                [if using an instance of AbsoluteTime
                    then
                        [reset the nextTargetTime to absoluteTime arg
                            and set last_rescheduled_with_AbsoluteTime = TRUE
                            and no state change]
                    else
                        [reset the nextDurationTime to relativeTime arg
                            and set last_rescheduled_with_AbsoluteTime = FALSE
                            and no state change]]]
    getFireTime ->
        return (currentTime + durationTime - countingTime)

```



```

destroy -> go to state {destroyed}
startDisabled -> throws IllegalStateException

```

```

{destroyed}
  enable — disable — stop — start — isRunning
  — reschedule — getFireTime — destroy
  — startDisabled -> throws IllegalStateException

```

The following two methods, without loss of generality and to avoid clutter, have been omitted from the above Pseudo-code.

Every state but {**destroyed**} has:

```

[(if PeriodicTimer) setInterval -> reset period = interval]
[(if PeriodicTimer) getInterval -> return period]

```

The state {**destroyed**} has:

```

[(if PeriodicTimer) setInterval -> throws IllegalStateException]
[(if PeriodicTimer) getInterval -> throws IllegalStateException]

```

10.4.2.5.2 Compact Graphic Representation of State Transitions for Timer

The following compact graphic representation, while not as detailed, complements the State Transitions for Timer pseudo-code:

(see image at doc-files/timers_state_machine.gif)

10.4.2.5.3 Constructors

Timer(HighResolutionTime, AsyncEventHandler, TimeDispatcher)

Signature

```

protected
Timer(javax.realtime.HighResolutionTime<?> time,
      AsyncEventHandler handler,
      TimeDispatcher dispatcher)

```

throws `IllegalArgumentException`,
 `UnsupportedOperationException`,
 `IllegalAssignmentError`

Create a timer that fires according to the given `time`, based on the `Clock`⁷⁹ clock and is handled by the specified `AsyncEventHandler`⁸⁰ handler.

Parameters

`time` The time used to determine when to fire the event. A `time` value of `null` is equivalent to a `RelativeTime` of 0, and in this case the `Timer` fires immediately upon a call to `start()`.

`handler` The default handler to use for this event. When `null`, no handler is associated with the timer and nothing will happen when this event fires unless a handler is subsequently associated with the timer using the `addHandler()` or `setHandler()` method.

`dispatcher` The dispatcher used to interface between this timer and its associated clock. When `null`, the system default dispatcher is used.

Throws

`IllegalArgumentException` when `time` is a negative `RelativeTime` value.

`UnsupportedOperationException` when `time` has a `Chronograph`⁸¹ is not a clock.

`IllegalAssignmentError` when this `Timer` cannot hold references to handler and clock.

10.4.2.5.4 Methods

`getClock`

Signature

```
public  
    javax.realtime.Clock getClock()  
throws IllegalStateException
```

Return the instance of `Clock`⁸² on which this timer is based.

⁷⁹Section 10.4.2.1

⁸⁰Section 8.4.3.5

⁸¹Section 10.4.1.2

⁸²Section 10.4.2.1

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

The instance of `Clock`⁸³ associated with this `Timer`.

getStartTime

Signature

```
public  
java.xml.realtime.HighResolutionTime<?> getStartTime()
```

Get the start time of this `Timer`. Note that the start time uses copy semantics, so changes made to the value returned by this method do not effect the start time of this `Timer`.

Returns

a reference to the time (or start) parameter used when constructing this `Timer`.
Since RTSJ 2.0

getEffectiveStartTime

Signature

```
public  
java.xml.realtime.AbsoluteTime getEffectiveStartTime()  
throws IllegalStateException,  
        ArithmeticException
```

Return a newly-created time representing the time the timer actually started, or when the timer has been rescheduled, the effective start time after the reschedule.

Throws

`IllegalStateException` when the timer is not active or has been destroyed.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

the time `this` actually started.

getEffectiveStartTime(AbsoluteTime)

Signature

⁸³Section 10.4.2.1

```
public
    javax.realtime.AbsoluteTime getEffectiveStartTime(AbsoluteTime dest)
    throws IllegalStateException,
        ArithmeticException
```

Update **dest** to represent the time the timer actually started, or when the timer has been rescheduled, the effective start time after the reschedule. When **dest** is **null**, behave as if [getEffectiveStartTime\(\)](#)⁸⁴ had been called.

Parameters

dest a place to store the time **this** actually started.

Throws

IllegalStateException when the timer is not active or has been destroyed.

ArithmeticException when the result does not fit in the normalized format.

Returns

The time the timer actually started, or when it has been rescheduled, the effective start time after the reschedule.

getLastReleaseTime

Signature

```
public final
    javax.realtime.AbsoluteTime getLastReleaseTime()
```

Get the last release time of this timer.

Throws

IllegalStateException when this timer has not been released since it was last started.

Returns

a reference to a newly-created [AbsoluteTime](#)⁸⁵ object representing this timer's last release time. When the timer has not been released since it was last started, throw an exception.

getLastReleaseTime(AbsoluteTime)

Signature

```
public
    javax.realtime.AbsoluteTime getLastReleaseTime(AbsoluteTime dest)
```

⁸⁴Section [10.4.2.5.4](#)

⁸⁵Section [9.4.1.1](#)

Returns

When `dest` is `null`, return a reference to a newly-created `AbsoluteTime`⁸⁶ object representing this timer's last release time. When `dest` is non-null, set `dest` to this timer's last release time. When the timer has not been released, return `null`. Since RTSJ 2.0

getFireTime*Signature*

```
public
  javax.realtime.AbsoluteTime getFireTime()
  throws IllegalStateException,
         ArithmeticException
```

Get the time at which this `Timer` is expected to fire. When the `Timer` is *disabled*, the returned time is that of the skipping of the firing. When the `Timer` is *not-active* it throws `IllegalStateException`.

Throws

`ArithmeticException` when the result does not fit in the normalized format.
`IllegalStateException` when this `Timer` has been *destroyed*, or when it is *not-active*.

Returns

The absolute time at which `this` is expected to fire (release handlers or skip), in a newly allocated `AbsoluteTime`⁸⁷ object. When the timer has been created or re-scheduled (see `Timer.reschedule`⁸⁸) using an instance of `RelativeTime` for its time parameter then it will return the sum of the current time and the `RelativeTime` remaining time before the timer is expected to fire/skip. The clock association of the returned time is the clock on which `this` timer is based.

getFireTime(AbsoluteTime)*Signature*

```
public
  javax.realtime.AbsoluteTime getFireTime(AbsoluteTime dest)
```

⁸⁶Section 9.4.1.1

⁸⁷Section 9.4.1.1

⁸⁸Section 10.4.2.5.4

throws `IllegalStateException`,
`ArithmeticException`

Get the time at which this `Timer` is expected to fire. When the `Timer` is *disabled*, the returned time is that of the skipping of the firing. When the `Timer` is *not-active* it throws `IllegalStateException`.

Parameters

dest The instance of `AbsoluteTime`⁸⁹ which will be updated in place and returned. The clock association of the **dest** parameter is ignored. When **dest** is `null` a new object is allocated for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.
`IllegalStateException` when this `Timer` has been *destroyed*, or when it is *not-active*.

Returns

The instance of `AbsoluteTime`⁹⁰ passed as parameter, with time values representing the absolute time at which **this** is expected to fire (release its handlers or skip). When the **dest** parameter is `null` the result is returned in a newly allocated object. When the timer has been created or rescheduled (see `Timer.reschedule`⁹¹) using an instance of `RelativeTime` for its time parameter then it will return the sum of the current time and the `RelativeTime` remaining time before the timer is expected to fire. The clock association of the returned time is the clock on which **this** timer is based.

getDispatcher

Signature

```
public  
javax.realtime.TimeDispatcher getDispatcher()
```

isActive

Signature

```
public  
boolean isActive()
```

⁸⁹Section 9.4.1.1

⁹⁰Section 9.4.1.1

⁹¹Section 10.4.2.5.4

Determine the activation state of this happening, i.e., it has been started.

Returns

`true` when active, `false` otherwise.

isRunning

Signature

```
public
boolean isRunning()
throws IllegalStateException
```

Determines if `this` is *active* and is *enabled* such that when the given time occurs it will fire the event. Given the `Timer` current state it answer the question "*Is firing expected?*".

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

`true` when the timer is *active* and *enabled*; otherwise `false`, when the timer has either not been *started*, it has been *started* but it is *disabled*, or it has been *started* and is now *stopped*.

handledBy(AsyncEventHandler)

Signature

```
public
boolean handledBy(AsyncEventHandler handler)
throws IllegalStateException
```

Parameters

`handler` to add to the `Timer`

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

`true` when `handler` is associated with `this`, otherwise `false`.

createReleaseParameters

Signature

```
public
  javax.realtime.ReleaseParameters createReleaseParameters()
  throws IllegalStateException
```

Create a [ReleaseParameters](#)⁹² object appropriate to the timing characteristics of this event. The default is the most pessimistic: [AperiodicParameters](#)⁹³. This is typically called by code that is setting up a **handler** for this event that will fill in the parts of the release parameters for which it has values, e.g. cost.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

A newly created [ReleaseParameters](#)⁹⁴ object.

addHandler(AsyncEventHandler)

Signature

```
public
  void addHandler(AsyncEventHandler handler)
  throws IllegalStateException,
         IllegalAssignmentError
```

Add a handler to release upon fire.

Parameters

`handler` to add to the `Timer`

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

`IllegalAssignmentError`

setHandler(AsyncEventHandler)

Signature

```
public
  void setHandler(AsyncEventHandler handler)
  throws IllegalStateException,
         IllegalAssignmentError
```

⁹²Section [6.4.2.9](#)

⁹³Section [6.4.2.2](#)

⁹⁴Section [6.4.2.9](#)

Set a handler and remove all others.

Parameters

handler to add to the Timer

Throws

IllegalStateException when this Timer has been *destroyed*.

IllegalAssignmentError

removeHandler(AsyncEventHandler)

Signature

```
public
void removeHandler(AsyncEventHandler handler)
throws IllegalStateException
```

Remove the given handler.

Parameters

handler to add to the Timer

Throws

IllegalStateException when this Timer has been *destroyed*.

enable

Signature

```
public
void enable()
throws IllegalStateException
```

Re-enable this timer after it has been *disabled*. (See `Timer.disable()`⁹⁵.) When the Timer is already *enabled*, this method does nothing. When the Timer is *not-active*, this method does nothing.

Throws

IllegalStateException when this Timer has been *destroyed*.

disable

Signature

⁹⁵Section 10.4.2.5.4

```
public
void disable()
throws IllegalStateException
```

Disable this timer, preventing it from firing. It may subsequently be re-*enabled*. When the timer is *disabled* when its fire time occurs then it will not release its handlers. However, a *disabled* timer created using an instance of **RelativeTime** for its time parameter continues to count while it is *disabled*, and no changes take place in a *disabled* timer created using an instance of **AbsoluteTime**, in both cases the potential firing is simply masked, or skipped. When the timer is subsequently re-*enabled* before its fire time and it is *enabled* when its fire time occurs, then it will fire. It is important to note that this method does not delay the time before a possible firing. For example, when the timer is set to fire at time 42 and the **disable()** is called at time 30 and **enable()** is called at time 40 the firing will occur at time 42 (not time 52). These semantics imply also that firings are not queued. Using the above example, when enable was called at time 43 no firing will occur, since at time 42 **this** was *disabled*. When the **Timer** is already *disabled*, whether it is *active* or *inactive*, this method does nothing.

Throws

IllegalStateException when this **Timer** has been *destroyed*.

start

Signature

```
public
void start()
throws IllegalStateException
```

Start this timer. A timer starts measuring time from when it is started; this method makes the timer *active* and *enabled*.

Throws

IllegalStateException when this **Timer** has been *destroyed*, or when this timer is already *active*.

start(boolean)

Signature

```
public
void start(boolean disabled)
```

throws `IllegalStateException`

Start this timer. A timer starts measuring time from when it is started. When `disabled` is `true` start the timer making it *active* in a *disabled* state. When `disabled` is `false` this method behaves like the `start()` method.

Parameters

`disabled` When `true`, the timer will be *active* but *disabled* after it is started. When `false` this method behaves like the `start()` method.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*, or when this timer is *active*.

stop

Signature

```
public
boolean stop()
throws IllegalStateException
```

Stops a timer when it is *active* and changes its state to *inactive* and *disabled*.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

`true` when this was *enabled* and `false` otherwise.

reschedule(HighResolutionTime)

Signature

```
public
void reschedule(javax.xml.realtime.HighResolutionTime<?> time)
throws IllegalStateException,
    IllegalArgumentException
```

Change the scheduled time for this event. This method can take either an `AbsoluteTime` or a `RelativeTime` for its argument, and the `Timer` will behave as if created using that type for its `time` parameter. The rescheduling will take place between the invocation and the return of the method.

NOTE: While the scheduled time is changed as described above, the rescheduling itself is applied only on the first firing (or on the first skipping when *disabled*) of a timer's activation. When `reschedule` is invoked after the current activation timer's

firing, then the rescheduled **time** will be effective only upon the next **start** or **startDisabled** command (which may need to be preceded by a **stop** command).

When **reschedule** is invoked with a **RelativeTime** **time** on an *active* timer before its first firing/skipping, then the rescheduled firing/skipping **time** is relative to the time of invocation.

Parameters

time The time to reschedule for this event firing. When **time** is **null**, the previous time is still the time used for the **Timer** firing. The clock associated with the parameter **time** is always ignored.

Throws

IllegalArgumentException when **time** is a negative **RelativeTime** value.

IllegalStateException when this **Timer** has been *destroyed*.

fire

Signature

```
public  
void fire()
```

Should not be called except for emulation. The **fire** method is reserved for the use of the timer. It releases all handlers when **this** is enabled and does nothing, otherwise.

10.5 Rationale

Clocks differ because of monotonicity, synchronization, jitter, stability, accuracy, precision, and resolution. There are many possible subclasses of clocks: realtime clocks, user time clocks, simulation time clocks, wall clocks.

The idea of using multiple clocks may at first seem unusual, but it enables the accommodation of different kinds of clocks and as a possible resource allocation strategy. Consider a realtime system where the natural events of the system have different tolerances for jitter. Assume the system functions properly if event *A* is triggered within plus or minus 100 seconds of the actual time it should occur but event *B* must be triggered within 100 microseconds of its actual time. Further assume, without loss of generality, that events *A* and *B* are periodic. An application could then create two instances of **PeriodicTimer** based on two clocks. The timer for event *B* should be based on a **Clock** which checks its queue at least every 100 microseconds but the timer for event *A* could be based on a **Clock** that checked its queue only every 100 seconds. This use of two clocks reduces the queue size of the accurate clock and thus queue management overhead is reduced.

The importance of the use of one-shot timers for time-out behavior and the vagaries in the execution of code prior to starting the timer for short time-outs dictate that the triggering of the timer should be guaranteed. The problem is exacerbated for periodic timers where the importance of the periodic triggering outweighs the precision of the start time. In such cases, it is also convenient to allow, for example, a relative time of zero to be used as the start time.

Clock resolution is a complicated topic, and clock implementations may have differing precision for different purposes. For example, a clock for interacting with humans need much less precision than for controlling the opening and closing of valves on an internal combustion engine. In this case, their relationship to wall clock time may vary as well.

The precision of time returned by a hardware clock device when queried may be greater than the precision at which that device can supply interrupts. (Consider, for example, a high precision off-chip realtime clock device connected via a shared serial bus.) A different device may provide pulse-per-second interrupts of very high precision, but be unable to interrupt on any other interval. The `RTSJ Clock` class provides two representation of precision: `getDrivePrecision()` and `getQueryPrecision` inherited from `Chronograph`. Clocks should behave as if their tick (`setAlarm()`) precision is the same as returned by `getResolution()`.

Chapter 11

Alternative Memory Areas

11.1 Overview

Conventional Java uses a single heap for storing all objects. The thread stacks hold only primitive objects and references to objects. This is fine for desktop and server systems, where there are no realtime, locality, or isolation requirements. For most realtime systems, a single heap with a deterministic garbage collector is usually also sufficient. For other situations, this specification defines classes directly related to memory and memory management. These classes provide a more generalized means of memory management than available in a conventional Java VM.

In conventional Java, all of the memory needed for the allocation of an object is taken from a garbage-collected heap. The RTSJ generalizes the concept of a heap to that of a *memory area*. A memory area consists of two components: a Java object that manages the memory area and the *backing memory*, which is the actual region of memory from which objects are allocated. Every thread and schedulable has a *current allocation context*. This context is the memory area which is managing the backing memory that will be used when the thread/schedulable requests memory allocation using the Java “new” operator.

There are three types of memory area, distinguished by object lifetime semantics, defined by the RTSJ.

- Heap memory—the Java heap. Unreachable objects are collected by a garbage collector. Individual schedulables can specify their rate of allocation of objects on the heap.
- Immortal memory—an area defined by the JVM in which allocated objects might never be collected. Access to the memory area must be independent of garbage collection activity. Individual schedulables can specify the maximum amount of memory they need in immortal memory.
- Scoped memory—multiple areas that can be created by the application; ob-

jects are collected in scoped memory when there are no schedulables currently active in that area and it is not pinned. These allow objects with well-defined lifetimes to be created and efficiently collected in an easily identified group.

Given that objects can now be created in multiple memory areas, it is necessary to ensure that an object cannot reference another object that might be collected at an earlier time. For example, an object in immortal memory (that is never collected) must not be allowed to reference an object in scoped memory. This is because the scoped memory object that is not pinned will be collected when there is no schedulable active in its associated backing memory, rendering the immortal object's reference to the scoped memory object invalid. For this reason, the RTSJ defines some memory assignment rules that are checked by the JVM on every object assignment. If the program violates the assignment rules, an exception is thrown.

11.1.1 Physical Memory

In embedded systems it is often the case that multiple directly addressable memory types are available to the application. The JVM implementer may require the VM to be portable between systems within the same processor family. The VM, therefore, may not have detailed knowledge of the underlying memory architecture. It is primarily concerned with the standard Random-Access Memory (RAM) provided to it by the host operating system. The RTSJ, therefore, provides a framework with which the embedded systems integrator can define memory characteristics and specify ranges of physical addresses that support those memory characteristics. Physical memory regions can be allocated as either immortal or scoped memory areas, as follows.

- Physical immortal memory—multiple immortal memory areas that can be created by the application such that their associated backing memory areas have specified physical and virtual memory characteristics. For example, the application could specify that the physical characteristics of the backing store should be Static RAM (SRAM) and that it should be mapped by the JVM into virtual memory that is never paged out to disk.
- Physical scoped memory—multiple scoped memory areas that can be created by the application such that their associated backing store has specified physical and virtual memory characteristics.

This physical memory model is based on two constraints.

- Java objects can only be allocated in a memory area if the physical backing memory supports the Java Memory Model (JMM) without the JVM having to perform any operation additional to those that it performs when accessing the main RAM for the host machine. No extra compiler or JVM interactions shall be required. Hence memory regions (such as EEPROM) that potentially require special hardware instructions to perform write operations cannot be

used as the backing store for physical memory areas. Similarly, non-volatile memory cannot be used, as object lifetimes in such an area may be longer than the lifetime of the VM. Although memory having such characteristics incompatible with the JMM are prohibited from being used as backing stores for object allocation, they can contain objects of primitive Java types and be accessed via the RTSJ Raw Memory facilities (see Section 12.3.1).

- Any API must delegate detailed knowledge of the memory architecture to the programmer/integrator of the specific embedded system to be implemented. The model assumes that the programmer is aware of the memory map, either through some native operating system interface¹ or from some property file read at program initialization time.

The RTSJ defines a *physical memory factory*, which maintains a mapping between physical memory characteristics and the associated physical addresses of memory that support those characteristics. The physical memory factory has no knowledge of the meaning of the physical characteristics. It only provides a look-up service and keeps track of which physical memory has been associated with a physical memory range by the application. The physical memory factory does, however, have detailed knowledge of the types of virtual memory it can support. It advertises this knowledge to the application. For example, it knows if the VM can lock memory pages into memory to ensure that they are never swapped out to disk. The application can then request that the physical memory manager create an association between physical memory with certain characteristics and a virtual memory type (for example, SRAM that is permanently resident in memory).

11.1.2 Stacked Memory

Systems that must both maintain predictable memory performance over a long period of time and allocate and release memory at runtime must be able to characterize and control both internal and external fragmentation. The RTSJ provides scoped memory for safe, application-driven allocation and release of memory, but the bare scoped memory interface (*e.g.*, `LMemory`) leaves sufficient ambiguity in specification that using it to create and release scopes at runtime in a fragmentation-free manner may depend on the VM platform. The `StackedMemory` class provides a safe interface for creating and releasing scopes with a set of rules under which the VM must guarantee fragmentation-free behavior with predictable memory overhead. These guarantees are provided by constraining the order in which an application may enter `StackedMemory` areas, as well as the manner in which they may be arranged on

¹For example, the *Advanced Configuration and Power Interface* (ACPI) specification is an open standard for device configuration and power management by the operating system. The ACPI defines platform-independent interfaces for hardware discovery, configuration, power management and monitoring. See <http://www.acpi.info/>

the scope stack. These constraints are to be enforced by the implementation.

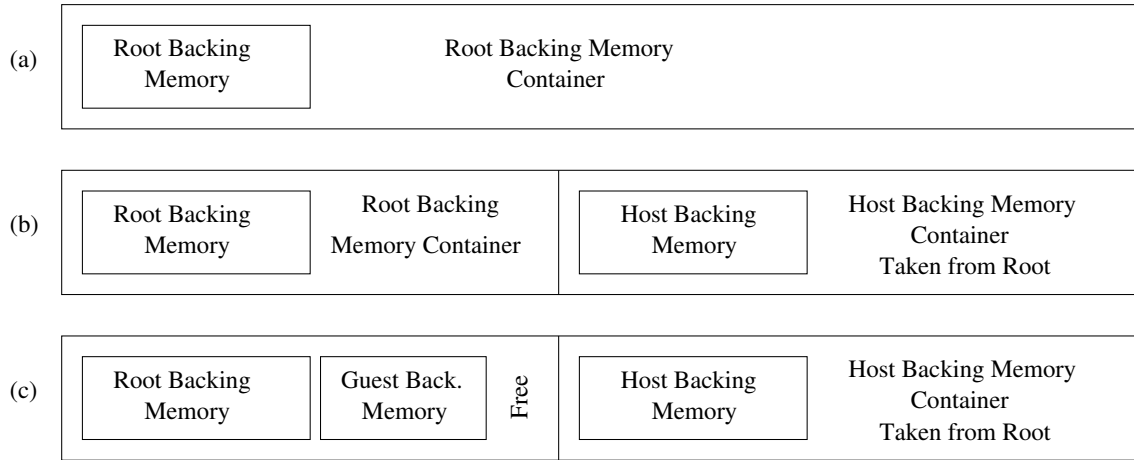
A **StackedMemory** area represents both a backing memory providing **ScopedMemory** semantics and a *backing memory container* from which the backing memory is drawn. The backing memory container may be further subdivided into additional backing memories and backing memory containers. Such divisions behave as if new containers are allocated contiguously from the bottom of the container, while new backing memories are allocated contiguously from the top, with containers and backing memories meeting when the container is completely occupied.

StackedMemory backing memory containers are explicitly created and sized, and have well-defined lifetimes similar to objects in a **ScopedMemory** area. A **StackedMemory** object can be created as either a *host*, which has its own backing memory container, or a *guest*, which draws its backing memory directly from its parent's backing memory container. When a **StackedMemory** object is created in an allocation context other than **StackedMemory**, it is necessarily a host and we call it a *root StackedMemory*. In this case, its backing memory container is drawn from a notional global backing memory container. Applications should assume that a root **StackedMemory**'s object is immortal, and implementations need not release it even if it is finalized. When a **StackedMemory** object is created in another **StackedMemory**'s allocation context, it may be created as either a host or guest, as illustrated in Figure 11.1. When it is created as a host, its backing memory container is drawn from its parent area's container, and its backing memory is created in the newly-divided container. When it is created as a guest, its backing memory is created in its parent's backing memory container.

Object lifetimes for objects allocated in **StackedMemory** backing memories are the same as those in **ScopedMemory** allocation areas. When a **StackedMemory** object itself is finalized, its backing memory is returned to the container from which it was drawn, and in the case of host **StackedMemory** areas, the associated backing memory container is also returned to the parent's container. As previously mentioned, root **StackedMemory** backing memory containers are effectively immortal. Additionally, the backing memory of a **StackedMemory** can be resized under certain conditions. These semantics allow the memory represented by a root **StackedMemory** backing memory container to be partitioned and re-partitioned as the application requires, without danger of fragmentation and without requiring memory allocation external to the container to track the partitioning.

In order to preserve the fragmentation-free nature of this contract, certain rules are enforced, and certain additional rules must be observed by the application. The rules that are enforced by the **StackedMemory** infrastructure are

- a non-root **StackedMemory** area can only be entered by a schedulable when its allocation context is the same as allocation context in which that **StackedMemory** area's object was created;

Figure 11.1: Manipulation of `StackedMemory` Areas

- a `StackedMemory` area may have at most one direct child in the scope stack that is a guest `StackedMemory` area;
- a `StackedMemory` object cannot be created from another `StackedMemory` allocation context unless it is allocated from that area's backing memory; and
- a `StackedMemory`'s backing memory cannot be resized if there are non-finalized guest `StackedMemory` backing memories placed after it in the same backing memory container.

The additional rules that are not enforced by the infrastructure are not enforced because it may be desirable for an application to temporarily violate them (*e.g.*, when joining child threads in completion order, rather than creation order). They nevertheless must be observed at critical times in order to preserve fragmentation-free allocation. They are that, when a new `StackedMemory` is created as either a host or guest in a particular container, one of the following conditions must be met:

- The new `StackedMemory` area is a host, and there are existing non-finalized host `StackedMemory` descendants in the parent backing memory, but all such descendants were *created after* all non-finalized host descendants. (That is, effectively last-in first-out finalization.)
- The new `StackedMemory` area is a host, and there are no existing non-finalized host `StackedMemory` descendants in the parent backing memory.
- The new `StackedMemory` area is a guest.

Note that the first bullet point effectively can be violated only if the parent has *both* host and guest children.

Figure 11.1 graphically depicts the behavior of `StackedMemory` backing memory containers and backing memories for a root `StackedMemory` as well as one host and one guest child `StackedMemory` under that root. A code fragment that could create the stack topology in Figure 11.1 is as follows. Assume that this fragment executes

in an allocation context other than a **StackedMemory**, and that zero overhead is required for memory area creation. (Implementations may require a constant amount of backing memory overhead for each **StackedMemory** area created in the store.)

```

1 // Create a StackedMemory with a 10 kB backing memory container and
2 // 2 kB backing memory
3 rootArea = new StackedMemory(2048, 10240); // (a)
4 rootArea.enter(new Runnable()
5 {
6     public void run()
7     {
8         // Create a host area with a 6 kB backing memory container and
9         // 2 kB backing memory
10        hostArea = new StackedMemory(2048, 6144); // (b)
11        // Create a guest area with a 2 kB backing memory
12        guestArea = new StackedMemory(1536); // (c)
13    }
14 });

```

Commented points (a), (b), and (c) correspond to their respective subfigures in Figure 11.1. At point (a), a root **StackedMemory** has been created with its 10 kB backing memory container drawn from the notional global container. It contains a 2 kB backing memory, which is then entered. With that backing memory as the current allocation context, a new host **StackedMemory** is created at (b), reserving 6 kB of the root **StackedMemory**'s backing memory container for its own use and creating a second 2 kB backing memory within that reservation. A new guest **StackedMemory** is then created at (c) in the root area (without entering the host child), occupying 1.5 kB of the remaining free 2 kB of the container in the root area. At this point, the root area's backing memory container is almost entirely occupied, with one 2 kB backing memory, one 1.5 kB backing memory, and a 6 kB host area backing memory container reservation, and 512 B of free backing memory container in between. The host **StackedMemory** created at (b) has 4 kB of its backing memory container remaining unoccupied in its reservation, which could be allocated to additional host or guest **StackedMemory** areas beneath it in the stack.

11.1.3 Summary

In summary, the classes and interfaces defined in this chapter enable

- the definition of regions of memory outside of the conventional Java heap;
- the definition of regions of scoped memory, that is, memory regions with a limited lifetime;
- the definition of regions of memory containing objects whose lifetime matches that of the application;

- the definition of regions of memory mapped to specific physical addresses with specific virtual memory characteristics;
- the specification of maximum memory area consumption and maximum allocation rates for individual schedulables;
- the programmer to query information characterizing the behavior of the garbage collection algorithm, and to some limited ability, alter the behavior of that algorithm.

11.2 Definitions

The following terms are used throughout this chapter.

Allocation Context—the place where a given task allocated new object. In conventional Java, this is the Java heap. This is just one type of `MemoryArea`, the base class representing all allocation contexts in the RTSJ.

Current allocation context—the memory area which will be used when object allocation is requested.

Backing store or backing memory—the area of memory that is managed by a `MemoryArea` and is logically separate from the Java heap.

Firable asynchronous event handler—An `AsyncBaseEventHandler` is *firable* whenever there is an agent that can release it. This includes cases when the `AsyncBaseEventHandler` is

- a miss handler, or overrun handler of a `RealtimeThread` instance that has been started but not yet terminated;
- a handler associated with an `AsyncEvent` that can be fired;
- a miss handler or overrun handler for an instance of `AsyncBaseEventHandler`.

It excludes the final stage of scoped memory wrap-up.

Execution context—the memory area upon which execution is dependent. This includes the area a `Schedulable` or `ActiveEvent` is allocated. In order to prevent references from becoming invalid, the memory of an execution context may not be reclaimed. A memory area containing one of the following is such a context:

- `Thread` instances that have been started and have not terminated (including the `RealtimeThread` instances contained by `ActiveEventDispatcher` instances),
- `AsyncBaseEvent` instances that have a least one associated `AsyncBaseEventHandler`,
- `ActiveEvent` instances that are active,
- Firable `AsyncBaseEventHandler` instance, and
- active threads of control which have the memory area enter on their stack.

Default initial memory area—The initial memory area for a schedulable is *default* when it is the memory area where the schedulable was created.

Portal—A reference inside a **ScopedMemory** instance settable on that instance which may reference an object in that area. A portal can be used to pass information between instances of **Schedulable** executing in a given area.

Scope stack—A stack of the memory areas the current **Schedulable** instance has entered in order of entry. in-use memory areas.

11.3 Semantics

The classes **MemoryArea**, **HeapMemory**, and **ImmortalMemory** are part of the base module and the semantics below that apply to those modules must be fulfilled by all RTSJ implementations. The rest of the features described here belong to the Alternate Memory Area Module introduced in Section 3.2.3 and are only required for implementations that include that module. The following lists define the general semantics of the classes of this section. Semantics of particular classes, constructors, methods, and fields are the class description and the constructor, method, and field detail sections further on.

11.3.1 Allocation Execution Time

The following two requirements apply to allocation in any memory area, including the heap.

1. Some **MemoryArea** classes are required to have linear (in object size) allocation time. The linear time attribute requires that, ignoring performance variations due to hardware caches or similar optimizations and ignoring execution time of any static initializers, the execution time of **new** must be bounded by a polynomial, $f(n)$, where n is the size of the object and for all $n > 0$, $f(n) \leq Cn$ for some constant C .
2. Execution time of object constructors, and time spent in class loading and static initialization are not governed by bounds on object allocation in this specification, but setting default initial values for fields in the instance (as specified in *The Java Virtual Machine Specification*, Second Edition, section 2.5.1, “Each class variable, instance variable, and array component is initialized with a default value when it is created.”) is considered part of object allocation and included in the time bound.

11.3.2 Allocation Context

The following requirements apply to the allocation context represented by a memory area.

3. A memory area is represented by an instance of a subclass of the `MemoryArea` class. When a memory area, *m*, is entered by calling `m.enter` (or another method from the family of enter-like methods defined in `MemoryArea` or its subclasses), *m* becomes the *allocation context* of the current schedulable object. When control returns from the `enter` method, the allocation context is restored to the value it had immediately before `enter` was called.
4. When a memory area, *m*, is entered by calling *m*'s `executeInArea` method, *m* becomes the current allocation context of the current schedulable. When control returns from the `executeInArea` method, the allocation context is restored to the value it had before `executeInArea` was called.
5. The initial allocation context for a schedulable is the memory area that was designated the *initial memory area* when the schedulable was constructed. This initial allocation context becomes the current allocation context for that schedulable when the schedulable object first becomes eligible for execution. For instances of `AsyncBaseEventHandler`, the initial allocation context is the same on each release; for realtime threads, in releases subsequent to the first, the allocation context is the same as it was when the realtime thread became *blocked-for-release-event*.
6. All object allocation through the `new` keyword will use the current allocation context, but note that allocation can be performed in a specific memory area using the `newInstance` and `newArray` methods.
7. Instances of `schedulables` behave as if they stored their memory area context in a structure called the *scope stack*. This structure is manipulated by the instantiation of a schedulables, and the following methods from `MemoryArea` and its subclasses: all the `enter` and `joinAndEnter` methods, `executeInArea`, and both `newInstance` methods. See the semantics in Maintaining the Scope Stack for details.
8. The scope stack is accessible through a set of static methods on `RealtimeThread`. These methods allow outer allocation contexts to be accessed by their index number. Memory areas on a scope stack may be referred to as *inner* or *outer* relative to other entries in that scope stack. An “outer scope” is further from the current allocation context on the current scope stack and has a lower index.
9. The `executeInArea`, `newInstance` and `newArray` methods, when invoked on an instance of `ScopedMemory` require that instance to be an outer allocation context on the current schedulable object's current scope stack.
10. An instance of `ScopedMemory` is said to be *in use* if it has a non-zero reference

count as defined by semantic 17 below.

11.3.3 The Parent Scope

The following requirements apply to a scope's parent.

11. Instances of **ScopedMemory** have special semantics including definition of *parent*. If a **ScopedMemory** object is neither in use nor the initial memory area for a schedulable, it has no *parent* scope.
 - (a) When a **ScopedMemory** object becomes in use, its parent is the nearest **ScopedMemory** object outside it on the current scope stack. If there is no outside **ScopedMemory** object in the current scope stack, the parent is the *primordial scope* which is not actually a memory area, but only a marker that constrains the parentage of **ScopedMemory** objects.
 - (b) At construction of a schedulable, if the initial memory area has no parent, the initial memory area is assigned the parent it will have when the schedulable is in execution. This rule determines the initial memory area's parent until the schedulable object is de-allocated or, in the case of a **RealtimeThread**, it completes execution.
12. Instances of **ScopedMemory** must satisfy the *single parent rule* which requires that each scoped memory has a unique parent as defined in semantic 11.

11.3.4 Memory Areas and Scheduling

The following requirements govern the relationship between memory and execution.

13. Pushing a scoped memory onto a scope stack is always subject to the single parent rule.
14. Each schedulable has an initial memory area which is that object's initial allocation context. The default initial memory area is the current allocation context in effect during execution of the schedulable's constructor, but schedulables may supply constructors that override the default.
15. A Java thread cannot have a scope stack; consequently it can only be created and execute within heap or immortal memory. The thread starts execution with its allocation context set to the memory area containing the **Thread** object. An attempt to create a Java thread in a scoped memory area throws **IllegalAssignmentError**.
16. A Java thread may use **executeInArea**, and the **newInstance** and **newArray** methods from the **ImmortalMemory** and **HeapMemory** classes. These methods allow it to execute with an immortal current allocation context, but semantic 15 applies even during execution of these methods.

11.3.5 Scoped Memory Reference Counting

The following requirements apply to references to scoped memory.

17. Each instance of the class `ScopedMemory` or its subclasses must maintain a reference count which is greater than zero if and only if either:
 - (a) the scoped memory area is the current allocation context or an outer allocation context for one or more *execution contexts*; or else
 - (b) the scoped memory area contains the *fireable* `AsyncEventHandler` that was created with the `pinInitialMemoryArea` flag set to `True`.
18. Each instance of the `PinnableMemory` class must support a pinned count. This count is incremented for each call of the `pin` method and decremented for each call of the `unpin` method. The count is always greater than or equal to zero (that is, calling the `unpin` method has no effect if the count equals zero).
19. When the reference count for an instance of the class `ScopedMemory` is ready to be decremented from one to zero and the pinned count (if present) is equal to zero, all unfinalized objects within that area are considered ready for finalization. If after the finalizers for all such unfinalized objects in the scoped memory area run to completion, the reference count for the memory area is still ready to be decremented to zero and the pinned count is still equal to zero, any newly created unfinalized objects are considered ready for finalization and the process is repeated until no new objects are created or the scoped memory's reference count is no longer ready to be decremented from one to zero. When the scope contains no unfinalized objects and its reference count is ready to be decremented from one to zero and the pinned count is equal to zero, any async event in the scope is no longer treated as a source of fireability for async event handlers. If that action causes object creation in the scope the finalization process resumes from the beginning, if the reference count is no longer ready to be decremented to zero the finalization process terminates, otherwise, the reference count is decremented to zero and the memory scope is emptied of all objects. The process of scope finalization starts when the scope's reference count is about to go to zero with a zero pin count and continues until the scope is emptied or the process is terminated because the reference count is no longer about to go to zero. The RTSJ implementation must behave effectively as if during the finalization process the SO executing the finalization of a scope held a synchronized lock that must also be acquired to increase the reference count when entering the scope, to increase the reference count during startup for a thread with the finalizing scope as its non-default initial memory area, and to increase the reference count while making fireable an AEH with the scope as its non-default initial memory area. Although the steps in scope finalization are ordered no order is specified for finalization of objects or for disarming fireability of AEHs. The objects may be processed in any order

or concurrently, but at no time may a scope's reference count be reduced to zero while it has one or more child scopes. (This semantic is a special case of the finalization implementation specified in *The Java Language Specification*, second edition, section 12.6.1.)

20. When the pinned count is ready to go to zero and the reference count is zero, all unfinalized objects within that area are considered ready for finalization, and the same semantics as 19 above applies.
21. Finalization may start when all unfinalized objects in the scope are ready for finalization. Finalizers are executed with the current allocation context set to the finalizing scope and are executed by the schedulable in control of the scope when its reference count is ready to be decremented from one to zero. If finalizers are executed because a realtime thread terminates or an **AsyncEventHandler** becomes non-fireable, that realtime thread or **AsyncEventHandler** is considered in control of the scope and must execute the finalizers.
22. From the time objects in a scope are deleted until the portal on the scope is successfully set to a non-null value with **setPortal**, the value returned by **getPortal** on that scoped memory object must be **null**.

11.3.6 Immortal Memory

The following requirements apply to immortal memory.

23. Objects created in any immortal memory area are unexceptionally referenceable from all Java threads, and all schedulables, and the allocation and use of objects in immortal memory is never subject to garbage collection delays.
24. An implementation may execute finalizers for immortal objects when it determines that the application has terminated. Finalizers will be executed by a thread or schedulable whose current allocation context is not scoped memory. Regardless of any call to **runFinalizersOnExit**, except as required to support the base Java platform, the system need not execute finalizers for immortal objects that remain unfinalized when the JVM begins termination.
25. Class objects, the associated static memory, and interned Strings behave effectively as if they were allocated in immortal memory with respect to reference rules, assignment rules, and preemption delays by no-heap schedulables. Static initializers are executed effectively as if the current thread performed **ImmortalMemory.instance().executeInArea(r)** where **r** is a **Runnable** that executes the **<clinit>** method of the class being initialized.

11.3.7 Maintaining Referential Integrity

The following rules apply to references to objects in scoped memory.

26. Assignment rules placed on reference assignments prevent the creation of dangling references, and thus maintain the referential integrity of the Java runtime. The restrictions are listed in the following table:

Stored in Area	Reference to Object in Heap	Reference to Object in Immortal	Reference to Object in Scoped	null
Heap	Permit	Permit	Forbid	Permit
Immortal	Permit	Permit	Forbid	Permit
Scoped	Permit	Permit	Permit from same or less deeply nested scope	Permit
Local Variable	Permit	Permit	Permit	Permit

For this table, `ImmortalMemory` and `ImmortalPhysicalMemory` are equivalent, and all sub-classes of `ScopedMemory` are equivalent.

27. An implementation must ensure that the above checks are performed for each assignment statement before the statement is executed, either by runtime checks or by static analysis of the application logic. Checks for operations on local variables are not required because a potentially invalid reference would be captured by the other checks before it reached a local variable.

11.3.8 Object Initialization

The following requirements apply to object initialization.

28. Static initializers run with the immortal memory area as their allocation context.
29. The current allocation context in a constructor for an object is the memory area in which the object is allocated. For `new`, this is the current allocation context when `new` was called. For members of the `m.newInstance` family, the current allocation context is memory area `m`.

11.3.9 Maintaining the Scope Stack

This section describes maintenance of a data structure that is called the *scope stack*. Implementations are not required to use a stack or implement the algorithms given here. It is only required that an implementation behave with respect to the ordering and accessibility of memory scopes effectively as if it implemented these algorithms. The scope stack is implicitly visible through the assignment rules, and the stack is explicitly visible through the static method `getOuterMemoryArea(int)` on `Real-timeThread`.

Four operations affect the scope stack: the `enter` methods defined in `MemoryArea` and its subclasses, instantiation of a new `Schedulable`, the `executeInArea` method

in `MemoryArea`, and the new instance methods in `MemoryArea`.

1. The memory area at the top of a schedulable object's scope stack is the schedulable's current allocation context.
2. When a schedulable, t , creates a schedulable object, n_t , in a `ScopedMemory` object's allocation area, n_t acquires a copy of the scope stack associated with t at the time n_t is constructed including all entries from up to and including the memory area containing n_t . If n_t is created in heap, immortal, or immortal physical memory, n_t is created with a scope stack containing only heap, immortal, or immortal physical memory respectively. If n_t has a non-default initial memory area, ima , then ima is pushed on n_t 's newly-created scope stack.
3. When a memory area, ma is entered by calling a `ma.enter` method, ma is pushed on the scope stack and becomes the *allocation context* of the current schedulable object. When control returns from the `enter` method, the allocation context is popped from the scope stack
4. When a memory area, m , is entered by calling m 's `executeInArea` method or one of the `m.newInstance` methods, the scope stack before the method call is preserved and replaced with a scope stack constructed as follows:
 - (a) when ma is a scoped memory area, the new scope stack is a copy of the schedulable's previous scope stack up to and including ma , and
 - (b) when ma is not a scoped memory area, the new scope stack includes only ma .

When control returns from the `executeInArea` method, the scope stack is restored to the value it had before `ma.executeInArea` or `ma.newInstance` was called.

For the purposes of these algorithms, stacks grow *up*. One should also note that the representative algorithms ignore important issues like freeing objects in scopes.

1. In every case, objects in a scoped memory area are eligible to be freed when the reference count for the area is zero after finalizers for that scope are run.
2. Informally, any objects in a scoped memory area *must* be freed and their finalizers run before the reference count for the memory area is incremented from zero to one.

11.3.10 The enter Method

For `ma.enter(logic)`:

```

1  push ma on the scope stack belonging to the current schedulable
2      -- which may throw ScopedCycleException
3  execute logic.run method
4  pop ma from the scope stack

```

11.3.11 The `executeInArea` or `newInstance` Methods

For `ma.executeInArea(logic)`, `ma.newInstance()`, or `ma.newArray()`:

```

1  when ma is an instance of heap immortal or ImmortalPhysicalMemory,
2      start a new scope stack containing only ma.
3      make the new scope stack the scope stack for the current
4          schedulable.
5  else if ma is in the scope stack for the current schedulable,
6      start a new scope stack containing ma and all
7          scopes below ma on the scope stack.
8      make the new scope stack the scope stack for the current
9          schedulable.
10 else
11     throw InaccessibleAreaException, execute logic.run,
12         or construct the object.
13     restore the previous scope stack for the current schedulable.
14     discard the new scope stack.
15 end

```

11.3.12 Constructor Methods for Schedulables

For construction of a schedulable in memory area `cma` with initial memory area of `ima`:

```

1  if cma is heap, immortal or ImmortalPhysicalMemory,
2      create a new scope stack containing cma.
3  else
4      start a new scope stack containing the entire
5          current scope stack.
6
7  if ima != cma
8      push ima on the new scope stack
9      -- which may throw ScopedCycleException.

```

The above pseudocode illustrates a straightforward implementation of this specification's semantics, but any implementation that behaves effectively like this one with respect to reference count values of zero and one is permissible. An implementation may be eager or lazy in maintenance of its reference count provided that it correctly implements the semantics for reference counts of zero and one.

11.3.13 The Single Parent Rule

Every push of a scoped memory type on a scope stack requires reference to the single parent rule, this enforces the invariant that every scoped memory area has no more than one parent.

The parent of a scoped memory area is identified by the following rules:

1. when the memory area is not currently on any scope stack, it has no parent;
2. when the memory area is the first scoped memory area on a scope stack, i.e., was entered from **ImmortalMemory** or **Heap**, its parent is the *primordial scope*,
3. otherwise, the parent is the first scoped memory area outside it on the scope stack, i.e., the scope from which this scope was entered.

Except for the primordial scope, which represents heap, immortal and immortal physical memory, only scoped memory areas are visible to the single parent rule.

The operational effect of the single parent rule is that when a scoped memory area has a parent, the only legal change to that value is to “no parent.” Thus an ordering imposed by the first assignments of parents of a series of nested scoped memory areas is the only nesting order allowed until control leaves the scopes; then a new nesting order is possible. Thus, a schedulable attempting to enter a scope can only do so by entering in the established nesting order.

11.3.14 Scope Tree Maintenance

The single parent rule is enforced effectively as if there were a tree with the primordial scope (representing heap, immortal, and immortal physical memory) at its root, and other nodes corresponding to every scoped memory area that is currently on any schedulable’s scope stack.

Each scoped memory has a reference to its parent memory area, **ma.parent**. The parent reference may indicate a specific scoped memory area, no parent, or the primordial parent.

If a scoped memory area is the non-default initial memory area of an async event handler, or the non-default initial memory area of a realtime thread that has not terminated, it is referred to as *pinned*.

11.3.14.1 On Scope Stack Push of MA

The following procedure could be used to maintain the scope tree and ensure that push operations on a schedulable’s scope stack do not violate the single parent rule.

```

1 precondition: ma.parent is set to the correct parent (either a scoped
2   memory area or the primordial scope) or to noParent.
3
4   t.scopeStack is the scope stack of the current schedulable
```

```
5
6  if ma is scoped,
7      parent = findFirstScope(t.scopeStack)
8  if ma.parent == noParent
9      ma.parent = parent.
10 else if ma.parent != parent
11     throw ScopedCycleException.
12 else
13     t.scopeStack.push(ma).
```

`findFirstScope` is a convenience function that looks down the scope stack for the next entry that is a reference to an instance of `ScopedMemoryArea`.

```
1 findFirstScope(scopeStack)
2 {
3   for s = top of scope stack to bottom of scope stack
4   if s is an instance of scopedMemory
5     return s return primordial scope
6 }
```

11.3.14.2 On Scope Stack Pop of ma

```
1 ma = t.scopeStack.pop.
2 if ma is scoped
3     if !(ma.in_use || ma.pinned)
4         ma.parent = noParent
```

11.4 Package *javax.realtime*

11.4.1 Interfaces

11.4.1.1 MemoryAreaVisitor

This interface is used to visit memory areas. For example, the method `MemoryArea.visitNestedMemory`² uses this visitor to process all memory areas nested the area upon which it is called.

11.4.1.1.1 Methods

`visit(MemoryArea)`

Signature

```
public  
R visit(MemoryArea memory)
```

Visit the members of a collection of memory areas. It provides a means of accessing all live scopes contained in a memory area, even those to which no reference exits, such a `javax.realtime.memory.PinnableMemory`³ that is pinned or another `ScopedMemory` that contains a `Schedulable`. The set may be concurrently modified by other tasks, but the view seen by the visitor may not be updated to reflect those changes.

Parameters

`memory` The memory area being visited.

Returns

Any object declared by the application or `null`. When `visit` returns an object, no more memory areas are visited and the `MemoryArea.visitNestedMemory`⁴ method returns the object returned by `visit(MemoryArea)`⁵.

²Section [11.4.2.3.2](#)

³Section [11.5.3.5](#)

⁴Section [11.4.2.3.2](#)

⁵Section [11.4.1.1.1](#)

11.4.2 Classes

11.4.2.1 HeapMemory

Inheritance

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.HeapMemory
```

The `HeapMemory` class is a singleton object that allows logic with a non-heap allocation context to allocate objects in the Java heap.

11.4.2.1.1 Methods

enter

Signature

```
public
void enter()
```

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the instance of `Runnable` given in the constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`⁶) or the `enter` method exits.

Throws

```
IllegalThreadStateException when the caller is a Java thread.
IllegalArgumentException
MemoryAccessError when caller is a no-heap schedulable.
```

enter(Runnable)

Signature

```
public
void enter(Runnable logic)
```

⁶Section [11.4.2.1.1](#)

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the given `Runnable`. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`⁷) or the `enter` method exits.

Parameters

`logic` The `Runnable` object whose `run()` method should be invoked.

Throws

`MemoryAccessError` when caller is a no-heap schedulable.

`IllegalThreadStateException`

`IllegalArgumentException`

instance

Signature

```
public static  
javax.realtime.HeapMemory instance()
```

Returns a reference to the singleton instance of `HeapMemory`⁸ representing the Java heap. The singleton instance of this class shall be allocated in the `ImmortalMemory`⁹ area.

Returns

The singleton `HeapMemory`¹⁰ object.

executeInArea(Runnable)

Signature

```
public  
void executeInArea(Runnable logic)
```

Execute the run method from the `logic` parameter using heap as the current allocation context. For a schedulable, this saves the current scope stack and replaces it with one consisting only of the `HeapMemory` instance; restoring the original scope stack upon completion.

Parameters

⁷Section 11.4.2.1.1

⁸Section 11.4.2.1

⁹Section 11.4.2.2

¹⁰Section 11.4.2.1

logic The runnable object whose `run()` method should be executed.

Throws

`IllegalArgumentException` when `logic` is null.

`MemoryAccessError` when caller is a no-heap schedulable.

newArray(Class, int)

Signature

```
public
java.lang.Object newArray(java.lang.Class<?> type,
                           int number)
```

Allocate an array of the given type in this memory area. This method may be concurrently used by multiple threads.

Parameters

type

number

Throws

`MemoryAccessError` when caller is a no-heap schedulable.

`IllegalArgumentException`

`OutOfMemoryError`

Returns

newInstance(Class)

Signature

```
public
java.lang.Object newInstance(java.lang.Class type)
throws IllegalAccessException,
    InstantiationException
```

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

type

Throws

`MemoryAccessError` when caller is a no-heap schedulable.

`IllegalAccessException`

IllegalArgumentException
ExceptionInInitializerError
OutOfMemoryError
InstantiationException

Returns

newInstance(Constructor, Object)

Signature

```
public  
java.lang.Object newInstance(java.lang.reflect.Constructor c,  
                             java.lang.Object[] args)  
  
throws IllegalAccessException,  
        InstantiationException,  
        InvocationTargetException
```

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

c T
args

Throws

MemoryAccessError when caller is a no-heap schedulable.
IllegalAccessException
InstantiationException
OutOfMemoryError
IllegalArgumentException
InvocationTargetException

Returns

visitNestedMemory(MemoryAreaVisitor)

Signature

```
public  
R visitNestedMemory(javax.realtime.MemoryAreaVisitor< R> visitor)
```

Visit each scoped memory area whose parent is the primordial scope and was created in heap memory.

Parameters

`visitor` invoke the `MemoryAreaVisitor.visit(MemoryArea)`¹¹ method for each member of the set of scoped memory areas that was created in heap memory and has the primordial scope as its parent.

Throws

`IllegalArgumentException`

Returns

11.4.2.2 `ImmutableMemory`

Inheritance

`java.lang.Object`
 `javax.realtime.MemoryArea`
 `javax.realtime.ImmutableMemory`

`ImmutableMemory` is a memory resource that is unexceptionally available to all schedulables and Java threads for use and allocation.

An immortal object may not contain references to any form of scoped memory, e.g., `javax.realtime.memory.LTMemory`¹², `javax.realtime.memory.StackedMemory`¹³, or `javax.realtime.memory.PinnableMemory`¹⁴.

Objects in immortal have the same states with respect to finalization as objects in the standard Java heap, but there is no assurance that immortal objects will be finalized even when the JVM is terminated.

Methods from `ImmutableMemory` should be overridden only by methods that use `super`.

11.4.2.2.1 Methods

instance

Signature

¹¹Section 11.4.1.1.1

¹²Section 11.5.3.1

¹³Section 11.5.3.7

¹⁴Section 11.5.3.5

```
public static  
    javax.realtime.ImmutableMemory instance()
```

Returns a pointer to the singleton [ImmutableMemory](#)¹⁵ object.

Returns

The singleton [ImmutableMemory](#)¹⁶ object.

executeInArea(Runnable)

Signature

```
public  
    void executeInArea(Runnable logic)
```

Execute the run method from the `logic` parameter using this memory area as the current allocation context. For a schedulable, this saves the current scope stack and replaces it with one consisting only of the `ImmutableMemory` instance; restoring the original scope stack upon completion.

Parameters

`logic` The runnable object whose `run()` method should be executed.

Throws

`IllegalArgumentException` when `logic` is null.

visitNestedMemory(MemoryAreaVisitor)

Signature

```
public  
    R visitNestedMemory(javax.realtime.MemoryAreaVisitor< R> visitor)
```

Visit each scoped memory area whose parent is the primordial scope and was created in this memory area.

Parameters

`visitor` invoke the [MemoryAreaVisitor.visit\(MemoryArea\)](#)¹⁷ method for each member of the set of scoped memory areas that was created in this immortal memory area and has the primordial scope as its parent.

Throws

`IllegalArgumentException`

Returns

¹⁵Section [11.4.2.2](#)

¹⁶Section [11.4.2.2](#)

¹⁷Section [11.4.1.1.1](#)

11.4.2.3 MemoryArea

Inheritance

java.lang.Object
javax.realtime.MemoryArea

MemoryArea is the abstract base class of all classes dealing with the representations of allocatable memory areas, including the immortal memory area, physical memory and scoped memory areas. This is an abstract class, but no method in this class is abstract. An application should not subclass **MemoryArea** without complete knowledge of its implementation details.

11.4.2.3.1 Constructors

MemoryArea(long)

Signature

```
protected  
MemoryArea(long size)  
throws IllegalArgumentException,  
        OutOfMemoryError
```

Create an instance of **MemoryArea**.

Parameters

size The size of **MemoryArea** to allocate, in bytes.

Throws

IllegalArgumentException when **size** is less than zero.

OutOfMemoryError when there is insufficient memory for the **MemoryArea** object or for the backing memory.

MemoryArea(SizeEstimator)

Signature

```
protected
MemoryArea(SizeEstimator size)
throws IllegalArgumentException,
        OutOfMemoryError
```

Create an instance of `MemoryArea`.

Parameters

size A `SizeEstimator`¹⁸ object which indicates the amount of memory required by this `MemoryArea`.

Throws

`IllegalArgumentException` when the `size` parameter is null, or `size.getEstimate()` is negative.

`OutOfMemoryError` when there is insufficient memory for the `MemoryArea` object or for the backing memory.

`MemoryArea(long, Runnable)`

Signature

```
protected
MemoryArea(long size,
            Runnable logic)
throws IllegalArgumentException,
        OutOfMemoryError,
        IllegalAssignmentError
```

Create an instance of `MemoryArea`.

Parameters

size The size of `MemoryArea` to allocate, in bytes.

logic The `run()` method of this object will be called whenever `enter()`¹⁹ is called. When `logic` is null, this constructor is equivalent to `MemoryArea(long size)`.

Throws

`IllegalArgumentException` when the `size` parameter is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `MemoryArea` object or for the backing memory.

¹⁸Section 11.4.2.5

¹⁹Section 11.4.2.3.2

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

MemoryArea(SizeEstimator, Runnable)

Signature

```
protected
MemoryArea(SizeEstimator size,
            Runnable logic)
throws IllegalArgumentException,
        OutOfMemoryError,
        IllegalAssignmentError
```

Create an instance of `MemoryArea`.

Parameters

`size` A `SizeEstimator` object which indicates the amount of memory required by this `MemoryArea`.

`logic` The `run()` method of this object will be called whenever `enter()`²⁰ is called. When `logic` is `null`, this constructor is equivalent to `MemoryArea(SizeEstimator size)`.

Throws

`IllegalArgumentException` when `size` is `null` or `size.getEstimate()` is negative.

`OutOfMemoryError` when there is insufficient memory for the `MemoryArea` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

11.4.2.3.2 Methods

enter

Signature

```
public
void enter()
```

²⁰Section 11.4.2.3.2

```
throws IllegalArgumentException,
        OutOfMemoryError,
        IllegalAssignmentError,
        MemoryAccessError
```

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the instance of `Runnable` given in the constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`²¹) or the `enter` method exits.

Throws

`IllegalThreadStateException` when the caller is a Java thread.

`IllegalArgumentException` when the caller is a schedulable and a `null` value for `logic` was supplied when the memory area was constructed.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`²², so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`²³ instance is preallocated by the VM to avoid cascading creation of `ThrowBoundaryError`²⁴.

`MemoryAccessError` when caller is a schedulable that may not use the heap and this memory area's `logic` value is allocated in heap memory.

enter(Runnable)

Signature

```
public
void enter(Runnable logic)
```

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the given `Runnable`. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`²⁵) or the `enter` method exits.

Parameters

²¹Section 11.4.2.3.2

²²Section 14.3.3.3

²³Section 14.3.3.7

²⁴Section 14.3.3.7

²⁵Section 11.4.2.3.2

`logic` The Runnable object whose `run()` method should be invoked.

Throws

`IllegalThreadStateException` when the caller is a Java thread.

`IllegalArgumentException` when the caller is a schedulable and `logic` is null.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`²⁶, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`²⁷ instance is preallocated by the VM to avoid cascading creation of `ThrowBoundaryError`.

enter(Supplier)

Signature

```
public  
T enter(java.util.function.Supplier< T> logic)
```

Same as `enter(Runnable)`²⁸ except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(BooleanSupplier)

Signature

```
public  
boolean enter(BooleanSupplier logic)
```

Same as `enter(Runnable)`²⁹ except that the executed method is called `get` and a `boolean` is returned.

Parameters

`logic` the object who's `get` method will be executed.

²⁶Section 14.3.3.3

²⁷Section 14.3.3.7

²⁸Section 11.4.2.3.2

²⁹Section 11.4.2.3.2

Returns

a result from the computation.

enter(IntSupplier)*Signature*

```
public  
int enter(IntSupplier logic)
```

Same as `enter(Runnable)`³⁰ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(LongSupplier)*Signature*

```
public  
long enter(LongSupplier logic)
```

Same as `enter(Runnable)`³¹ except that the executed method is called `get` and a `long` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(DoubleSupplier)*Signature*

```
public  
double enter(DoubleSupplier logic)
```

³⁰Section 11.4.2.3.2

³¹Section 11.4.2.3.2

Same as `enter(Runnable)`³² except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

getMemoryArea(Object)

Signature

```
public static  
javax.realtime.MemoryArea getMemoryArea(Object object)
```

Gets the `MemoryArea` in which the given object is located.

Throws

`IllegalArgumentException` when the value of `object` is `null`.

Returns

The instance of `MemoryArea` from which `object` was allocated.

memoryConsumed

Signature

```
public  
long memoryConsumed()
```

For memory areas where memory is freed under program control this returns an exact count, in bytes, of the memory currently used by the system for the allocated objects. For memory areas (such as heap) where the definition of "used" is imprecise, this returns the best value it can generate in constant time.

Returns

The amount of memory consumed in bytes.

memoryRemaining

Signature

```
public  
long memoryRemaining()
```

³²Section [11.4.2.3.2](#)

An approximation to the total amount of memory currently available for future allocated objects, measured in bytes.

Returns

The amount of remaining memory in bytes.

newArray(Class, int)

Signature

```
public
java.lang.Object newArray(java.lang.Class<?> type,
                           int number)

throws IllegalArgumentException,
       OutOfMemoryError,
       SecurityException
```

Allocate an array of the given type in this memory area. This method may be concurrently used by multiple threads.

Parameters

type The class of the elements of the new array. To create an array of a primitive type use a **type** such as `Integer.TYPE` (which would call for an array of the primitive `int` type.)

number The number of elements in the new array.

Throws

`IllegalArgumentException` when **number** is less than zero, **type** is `null`, or **type** is `java.lang.Void.TYPE`.

`OutOfMemoryError` when space in the memory area is exhausted.

`SecurityException` when the caller does not have permission to create a new instance.

Returns

A new array of class **type**, of **number** elements.

newInstance(Class)

Signature

```
public
T newInstance(java.lang.Class< T> type)

throws IllegalAccessException,
       IllegalArgumentException,
       InstantiationException,
```

OutOfMemoryError,
ExceptionInInitializerError,
SecurityException

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

type The class of which to create a new instance.

Throws

IllegalArgumentException The class or initializer is inaccessible.

IllegalArgumentException when **type** is null.

InstantiationException when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array, or an exception was thrown by the constructor.

OutOfMemoryError when space in the memory area is exhausted.

ExceptionInInitializerError when an unexpected exception has occurred in a static initializer

SecurityException when the caller does not have permission to create a new instance.

Returns

A new instance of class **type**.

newInstance(Constructor, Object)

Signature

```
public  
T newInstance(java.lang.reflect.Constructor< T> c,  
              java.lang.Object[] args)  
throws ExceptionInInitializerError,  
       IllegalArgumentException,  
       IllegalArgumentException,  
       InstantiationException,  
       InvocationTargetException,  
       OutOfMemoryError,  
       SecurityException
```

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

c The constructor for the new instance.

args An array of arguments to pass to the constructor.

Throws

ExceptionInInitializerError when an unexpected exception has occurred in a static initializer

IllegalAccessException when the class or initializer is inaccessible under Java access control.

IllegalArgumentException when **c** is **null**, or the **args** array does not contain the number of arguments required by **c**. A **null** value of **args** is treated like an array of length 0.

InstantiationException when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array.

InvocationTargetException when the underlying constructor throws an exception.

OutOfMemoryError when space in the memory area is exhausted.

SecurityException when the caller does not have permission to create a new instance.

Returns

A new instance of the object constructed by **c**.

size

Signature

```
public  
long size()
```

Query the size of the memory area. The returned value is the current size. Current size may be larger than initial size for those areas that are allowed to grow.

Returns

The size of the memory area in bytes.

executeInArea(Runnable)

Signature

```
public  
void executeInArea(Runnable logic)  
throws IllegalArgumentException
```


Execute the run method from the `logic` parameter using this memory area as the current allocation context. The effect of `executeInArea` on the scope stack is specified in the subclasses of `MemoryArea`.

Parameters

`logic` The runnable object whose `run()` method should be executed.

Throws

`IllegalArgumentException` when `logic` is null.

executeInArea(Supplier)

Signature

```
public  
T executeInArea(java.util.function.Supplier< T> logic)
```

Same as `executeInArea(Runnable)`³³ except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(BooleanSupplier)

Signature

```
public  
boolean executeInArea(BooleanSupplier logic)
```

Same as `executeInArea(Runnable)`³⁴ except that the executed method is called `get` and a `boolean` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(IntSupplier)

Signature

³³Section 11.4.2.3.2

³⁴Section 11.4.2.3.2

```
public
int executeInArea(IntSupplier logic)
```

Same as `executeInArea(Runnable)`³⁵ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(LongSupplier)

Signature

```
public
long executeInArea(LongSupplier logic)
```

Same as `executeInArea(Runnable)`³⁶ except that the executed method is called `get` and a `long` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(DoubleSupplier)

Signature

```
public
double executeInArea(DoubleSupplier logic)
```

Same as `executeInArea(Runnable)`³⁷ except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

³⁵Section [11.4.2.3.2](#)

³⁶Section [11.4.2.3.2](#)

³⁷Section [11.4.2.3.2](#)

visitNestedMemory(MemoryAreaVisitor)

Signature

```
public  
R visitNestedMemory(javax.realtime.MemoryAreaVisitor< R> visitor)  
throws IllegalArgumentException
```

A means of accessing all live nested memory areas contained in this memory area, even those to which no reference exists, such a `javax.realtime.memory.PinnableMemory`³⁸ that is pinned or another `javax.realtime.memory.ScopedMemory` that contains a `Schedulable`. The set may be concurrently modified by other tasks, but the view seen by the visitor may not be updated to reflect those changes. The following is guarantees even when the set is disturbed by other tasks:

- the visitor shall visit no member more than once,
- it shall visit only scopes that were a member of the set at some time during the enumeration of the set, and
- it shall visit all the scopes that are not deleted during the execution of the visitor.

Perform an action on all children scopes of this memory area, so long as the `MemoryAreaVisitor.visit(MemoryArea)`³⁹ method returns `null`. When that method returns an object, the visit is terminated and that object is returned by this method,

When execution of the visitor's visit method terminated abruptly by throwing an exception, then execution of `visitScopedChildren` also terminates abruptly by throwing the same exception.

Parameters

`visitor` determines the action to be performed on each of the children scopes.

Throws

`IllegalArgumentException` when visitor is `null`.

Returns

`null` when all elements were visited and some object of type `R` when the visit is forced to terminate at the end of visiting that element.

mayHoldReferenceTo

Signature

```
public  
boolean mayHoldReferenceTo()
```

³⁸Section 11.5.3.5

³⁹Section 11.4.1.1.1

Determine whether an object **A** allocated in the memory area represented by **this** can hold a reference to an object **B** allocated in the current memory area.

Returns

true when **B** can be assigned to a field of **A**, otherwise **false**.

mayHoldReferenceTo(Object)

Signature

```
public  
boolean mayHoldReferenceTo(Object value)
```

Determine whether an object **A** allocated in the memory area represented by **this** can hold a reference to the object **value**.

Parameters

value is the object to test.

Returns

true when **value** can be assigned to a field of **A**, otherwise **false**.

11.4.2.4 MemoryParameters

Inheritance

```
java.lang.Object  
  javax.realtime.MemoryParameters
```

Interfaces

```
Cloneable  
Serializable
```

Memory parameters can be given on the constructor of **RealtimeThread**⁴⁰ and **Async-EventHandler**⁴¹. These can be used both for the purposes of admission control by the scheduler and for the purposes of pacing the garbage collector (if any) to satisfy all of the schedulable memory allocation rates.

The limits in a **MemoryParameters** instance are enforced when a schedulable creates a new object, e.g., uses the **new** operation. When a schedulable exceeds its allocation or allocation rate limit, the error is handled as if the allocation failed because of insufficient memory. The object allocation throws an **OutOfMemoryError**.

When a reference to a **MemoryParameters** object is given as a parameter to a constructor, the **MemoryParameters** object becomes bound to the object being created. Changes to the values in the **MemoryParameters** object affect the constructed

⁴⁰Section 5.3.2.2

⁴¹Section 8.4.3.5

object. When given to more than one constructor, then changes to the values in the `MemoryParameters` object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

A `MemoryParameters` object may be shared, but that does not cause the memory budgets reflected by the parameter to be shared among the schedulables that are associated with the parameter object.

11.4.2.4.1 Fields

NO_MAX

```
public static final NO_MAX
```

Specifies no maximum limit.

11.4.2.4.2 Constructors

MemoryParameters(boolean)

Signature

```
public  
MemoryParameters(boolean mayUseHeap)
```

Create a `MemoryParameters` object with the given values.

Parameters

`mayUseHeap` indicates whether or not the schedulable may use the heap. The default is `true` when an instance of this class is not provided.

MemoryParameters(long, long, boolean)

Signature

```
public  
MemoryParameters(long maxMemoryArea,  
                  long maxImmortal,
```

`boolean mayUseHeap)`

Create a `MemoryParameters` object with the given values.

Parameters

maxMemoryArea A limit on the amount of memory the schedulable may allocate in its initial memory area. Units are in bytes. When zero, no allocation allowed in the memory area. To specify no limit, use `NO_MAX`.

maxImmortal A limit on the amount of memory the schedulable may allocate in the immortal area. Units are in bytes. When zero, no allocation allowed in immortal. To specify no limit, use `NO_MAX`.

mayUseHeap indicates whether or not the schedulable may use the heap. The default is `true` when an instance of this class is not provided.

Throws

`IllegalArgumentException` when any value other than positive. zero, or `NO_MAX` is passed as the value of **maxMemoryArea** or **maxImmortal**.

MemoryParameters(long, long)

Signature

```
public
MemoryParameters(long maxMemoryArea,
                  long maxImmortal)
```

Create a `MemoryParameters` object with the given values and `{link #mayUseHeap}` returns `false`.

Parameters

maxMemoryArea A limit on the amount of memory the schedulable may allocate in its initial memory area. Units are in bytes. When zero, no allocation allowed in the memory area. To specify no limit, use `NO_MAX`.

maxImmortal A limit on the amount of memory the schedulable may allocate in the immortal area. Units are in bytes. When zero, no allocation allowed in immortal. To specify no limit, use `NO_MAX`.

Throws

`IllegalArgumentException` when any value other than positive. zero, or `NO_MAX` is passed as the value of **maxMemoryArea** or **maxImmortal**.

MemoryParameters(long, long, long)

Signature

```
public
MemoryParameters(long maxMemoryArea,
                  long maxImmortal,
                  long allocationRate)
```

Create a `MemoryParameters` object with the given values and `mayUseHeap`⁴² returns `true`.

Parameters

maxMemoryArea A limit on the amount of memory the schedulable may allocate in its initial memory area. Units are in bytes. When zero, no allocation allowed in the memory area. To specify no limit, use `NO_MAX`.

maxImmortal A limit on the amount of memory the schedulable may allocate in the immortal area. Units are in bytes. When zero, no allocation allowed in immortal. To specify no limit, use `NO_MAX`.

allocationRate A limit on the rate of allocation in the heap. Units are in bytes per second of wall clock time. When `allocationRate` is zero, no allocation is allowed in the heap. To specify no limit, use `NO_MAX`. Measurement starts when the schedulable is first released for execution (not when it is constructed.) Enforcement of the allocation rate is an implementation option. When the implementation does not enforce allocation rate limits, it treats all non-zero allocation rate limits as `NO_MAX`.

Throws

`IllegalArgumentException` when any value other than positive. zero, or `NO_MAX` is passed as the value of `maxMemoryArea` or `maxImmortal`, or `allocationRate`.

11.4.2.4.3 Methods

clone

Signature

```
public
java.lang.Object clone()
```

⁴²Section 11.4.2.4.3

Return a clone of **this**. This method should behave effectively as if it constructed a new object with the visible values of **this**.

- The new object is in the current allocation context.
- **clone** does not copy any associations from **this** and it does not implicitly bind the new object to a SO.
-

getAllocationRate

Signature

```
public  
long getAllocationRate()
```

Gets the limit on the rate of allocation in the heap. Units are in bytes per second.

Returns

The allocation rate in bytes per second. When zero, no allocation is allowed in the heap. When the returned value is **NO_MAX**⁴³ then the allocation rate on the heap is uncontrolled.

getMaxImmortal

Signature

```
public  
long getMaxImmortal()
```

Gets the limit on the amount of memory the schedulable may allocate in the immortal area. Units are in bytes.

Returns

The limit on immortal memory allocation. When zero, no allocation is allowed in immortal memory. When the returned value is **NO_MAX**⁴⁴ then there is no limit for allocation in immortal memory.

getMaxMemoryArea

Signature

⁴³Section 11.4.2.4.1

⁴⁴Section 11.4.2.4.1


```
public  
long getMaxMemoryArea()
```

Gets the limit on the amount of memory the schedulable may allocate in its initial memory area. Units are in bytes.

Returns

The allocation limit in the schedulable's initial memory area. When zero, no allocation is allowed in the initial memory area. When the returned value is `NO_MAX`⁴⁵ then there is no limit for allocation in the initial memory area.

mayUseHeap

Signature

```
public  
boolean mayUseHeap()
```

Determine whether or not this parameter object specifies that the heap may be used.

Returns

`true` when heap may be used and `false` otherwise.

setAllocationRate(long)

Signature

```
public  
void setAllocationRate(long allocationRate)
```

Sets the limit on the rate of allocation in the heap.

Parameters

`allocationRate` Units are in bytes per second of wall-clock time. When `allocationRate` is zero, no allocation is allowed in the heap. To specify no limit, use `NO_MAX`. Measurement starts when the schedulable starts (not when it is constructed.) Enforcement of the allocation rate is an implementation option. When the implementation does not enforce allocation rate limits, it treats all non-zero allocation rate limits as `NO_MAX`.

Throws

`IllegalArgumentException` when any value other than positive, zero, or `NO_MAX` is passed as the value of `allocationRate`.

⁴⁵Section [11.4.2.4.1](#)

11.4.2.5 SizeEstimator

Inheritance

java.lang.Object
 javax.realtime.SizeEstimator

This class maintains an estimate of the amount of memory required to store a set of objects.

SizeEstimator is a floor on the amount of memory that should be allocated. Many objects allocate other objects when they are constructed. **SizeEstimator** only estimates the memory requirement of the object itself, it does not include memory required for any objects allocated at construction time. When the instance itself is allocated in several parts (when for instance the object and its monitor are separate), the size estimate shall include the sum of the sizes of all the parts that are allocated from the same memory area as the instance. Alignment considerations, and possibly other order-dependent issues may cause the allocator to leave a small amount of unusable space, consequently the size estimate cannot be seen as more than a close estimate.

[See Section MemoryArea.MemoryArea\(SizeEstimator\)](#)

[See Section LTMemory.LTMemory\(SizeEstimator\)](#)

11.4.2.5.1 Constructors

SizeEstimator

Signature

```
public  
SizeEstimator()
```

11.4.2.5.2 Methods

reserve(Class, int)

Signature

```
public
void reserve(java.lang.Class c,
             int number)
```

Take into account additional **number** instances of Class **c** when estimating the size of the [MemoryArea](#)⁴⁶.

Parameters

c The class to take into account.

number The number of instances of **c** to estimate.

Throws

`IllegalArgumentException` when **c** is null.

reserve(SizeEstimator, int)

Signature

```
public
void reserve(SizeEstimator estimator,
             int number)
```

Take into account additional **number** instances of `SizeEstimator` **size** when estimating the size of the [MemoryArea](#)⁴⁷.

Parameters

estimator The given instance of [SizeEstimator](#)⁴⁸.

number The number of times to reserve the size denoted by **estimator**.

Throws

`IllegalArgumentException` when **estimator** is null.

reserve(SizeEstimator)

Signature

```
public
void reserve(SizeEstimator size)
```

⁴⁶Section [11.4.2.3](#)

⁴⁷Section [11.4.2.3](#)

⁴⁸Section [11.4.2.5](#)

Take into account an additional instance of `SizeEstimator` **size** when estimating the size of the `MemoryArea`⁴⁹.

Parameters

size The given instance of `SizeEstimator`.

Throws

`IllegalArgumentException` when **size** is null.

reserveArray(int)

Signature

```
public
void reserveArray(int length)
```

Take into account an additional instance of an array of **length** reference values when estimating the size of the `MemoryArea`⁵⁰.

Parameters

length The number of entries in the array.

Throws

`IllegalArgumentException` when **length** is negative.

reserveArray(int, Class)

Signature

```
public
void reserveArray(int length,
                  java.lang.Class type)
```

Take into account an additional instance of an array of **length** primitive values when estimating the size of the `MemoryArea`⁵¹.

Class values for the primitive types are available from the corresponding class types; e.g., `Byte.TYPE`, `Integer.TYPE`, and `Short.TYPE`.

Parameters

length The number of entries in the array.

type The class representing a primitive type. The reservation will leave room for an array of **length** of the primitive type corresponding to **type**.

Throws

⁴⁹Section 11.4.2.3

⁵⁰Section 11.4.2.3

⁵¹Section 11.4.2.3

`IllegalArgumentException` when `length` is negative, or `type` does not represent a primitive type.

getEstimate

Signature

```
public  
long getEstimate()
```

Gets an estimate of the number of bytes needed to store all the objects reserved.

Returns

The estimated size in bytes.

11.5 Package *javax.realtime.memory*

11.5.1 Interfaces

11.5.1.1 PhysicalMemoryCharacteristic

A tagging interface used to identify physical memory characteristics. Applications can give names to regions of memory that are described by *PhysicalMemoryRegion*⁵². The names are defined by creating instances of this interface. For example, `final static PhysicalMemoryCharacteristic STATIC_RAM = ...;`

11.5.1.2 VirtualMemoryCharacteristic

A tagging interface used to identify virtual memory characteristics. The *PhysicalMemoryFactory* defines static public objects that implement this interface. Each instant represent a particular virtual memory characteristics supported by the hosting machine.

For example, `public final static VirtualMemoryCharacteristic PERMANENTLY_RESIDENT`

11.5.1.2.1 Methods

apply(long, long)

Signature

```
public
void apply(long base,
           long size)
```

Apply the Characteristic to a given memory area.

Parameters

base is the physical start of the memory
size is the length of the memory in bytes.

⁵²Section [11.5.3.3](#)

unapply(long, long)

Signature

```
public
void unapply(long base,
              long size)
```

Unapply the Characteristic to a given memory area.

Parameters

base is the physical start of the memory
size is the length of the memory in bytes.

11.5.2 Enumerations

11.5.2.1 PhysicalMemorySelector.CachingBehavior

Inheritance

```
java.lang.Object
  java.lang.Enum
    javax.realtime.memory.PhysicalMemorySelector.CachingBehavior
```

Marker for standard caching behaviors. Not all need be supported. For example, a VM running in Kernel mode might only support DISABLED.

11.5.2.1.1 Enumeration Constants

DISABLED

```
public static final DISABLED
```

WRITE_THROUGH

```
public static final WRITE_THROUGH
```

WRITE_BACK

```
public static final WRITE_BACK
```

11.5.2.1.2 Methods

values

Signature

```
public static  
javax.realtime.memory.PhysicalMemorySelector.CachingBehavior[] values()
```

valueOf(String)

Signature

```
public static  
javax.realtime.memory.PhysicalMemorySelector.CachingBehavior valueOf(String name)
```

11.5.2.2 PhysicalMemorySelector.PagingBehavior

Inheritance

```
java.lang.Object  
  java.lang.Enum  
    javax.realtime.memory.PhysicalMemorySelector.PagingBehavior
```

Marker for standard paging behaviors. Not all need be supported. For example, a VM running in Kernel mode might only support `DIRECT`.

11.5.2.2.1 Enumeration Constants

DIRECT

```
public static final DIRECT
```

FIXED

```
public static final FIXED
```


SWAPPABLE

```
public static final SWAPPABLE
```

11.5.2.2.2 Methods

values

Signature

```
public static  
javafx.runtime.memory.PhysicalMemorySelector.PagingBehavior[] values()
```

valueOf(String)

Signature

```
public static  
javafx.runtime.memory.PhysicalMemorySelector.PagingBehavior valueOf(String name)
```

11.5.3 Classes

11.5.3.1 LTMemory

Inheritance

```
java.lang.Object  
  javafx.runtime.MemoryArea  
    javafx.runtime.memory.ScopedMemory  
      javafx.runtime.memory.LTMemory
```

LTMemory represents a memory area guaranteed by the system to have linear time allocation when memory consumption from the memory area is less than the memory area's *initial* size. Execution time for allocation is allowed to vary when memory consumption is between the initial size and the maximum size for the area. Furthermore, the underlying system is not required to guarantee that memory between initial and maximum will always be available.

The memory area described by a **LTMemory** instance does not exist in the Java heap, and is not subject to garbage collection. Thus, it is safe to use a **LTMemory**

object as the initial memory area for a `javax.realtime.Schedulable`⁵³ instance which may not use the `javax.realtime.HeapMemory`⁵⁴ or to enter the memory area using the `ScopedMemory.enter`⁵⁵ method within such an instance.

Enough memory must be committed by the completion of the constructor to satisfy the initial memory requirement. (Committed means that this memory must always be available for allocation). The initial memory allocation must behave, with respect to successful allocation, as if it were contiguous; i.e., a correct implementation must guarantee that any sequence of object allocations that could ever succeed without exceeding a specified initial memory size will always succeed without exceeding that initial memory size and succeed for any instance of `LTMemory` with that initial memory size. (Note: to ensure that all requested memory is available set initial and maximum to the same value) Methods from `LTMemory` should be overridden only by methods that use `super`.

See Section `javax.realtime.MemoryArea`

See Section `ScopedMemory`

See Section `javax.realtime.Schedulable`

11.5.3.1.1 Constructors

`LTMemory(long, long)`

Signature

```
public
    LTMemory(long initial,
             long maximum)
```

Create an `LTMemory` of the given size.

Parameters

initial The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

maximum The size in bytes of the memory to allocate for this area.

⁵³Section [6.4.1.3](#)

⁵⁴Section [11.4.2.1](#)

⁵⁵Section [15.3.3.11.2](#)

Throws

`IllegalArgumentException` when `initial` is greater than `maximum`, or when `initial` or `maximum` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

LTMemory(long, long, Runnable)

Signature

```
public
LTMemory(long initial,
         long maximum,
         Runnable logic)
```

Create an `LTMemory` of the given size.

Parameters

`initial` The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

`maximum` The size in bytes of the memory to allocate for this area.

`logic` The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LTMemory(long initial, long maximum)`⁵⁶.

Throws

`IllegalArgumentException` when `initial` is greater than `maximum`, or when `initial` or `maximum` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`javax.realtime.IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

LTMemory(SizeEstimator, SizeEstimator)

Signature

```
public
LTMemory(SizeEstimator initial,
```

⁵⁶Section [15.3.3.2.1](#)

SizeEstimator maximum)

Create an LTMemory of the given size.

Parameters

initial An instance of [SizeEstimator](#)⁵⁷ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

maximum An instance of [SizeEstimator](#)⁵⁸ used to give an estimate for the maximum bytes to allocate for this area.

Throws

`IllegalArgumentException` when **initial** is null, **maximum** is null, **initial.getEstimate()** is greater than **maximum.getEstimate()**, or when **initial.getEstimate()** is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the LTMemory object or for the backing memory.

LTMemory(SizeEstimator, SizeEstimator, Runnable)

Signature

```
public
LTMemory(SizeEstimator initial,
          SizeEstimator maximum,
          Runnable logic)
```

Create an LTMemory of the given size.

Parameters

initial An instance of [SizeEstimator](#)⁵⁹ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

maximum An instance of [SizeEstimator](#)⁶⁰ used to give an estimate for the maximum bytes to allocate for this area.

logic The `run()` of the given `Runnable` will be executed using **this** as its initial memory area. When **logic** is null, this constructor is equivalent to [LTMemory\(SizeEstimator initial, SizeEstimator maximum\)](#)⁶¹.

⁵⁷Section [11.4.2.5](#)

⁵⁸Section [11.4.2.5](#)

⁵⁹Section [11.4.2.5](#)

⁶⁰Section [11.4.2.5](#)

⁶¹Section [15.3.3.2.1](#)

Throws

`IllegalArgumentException` when `initial` is `null`, `maximum` is `null`, `initial.getEstimate()` is greater than `maximum.getEstimate()`, or when `initial.getEstimate()` is less than zero.

`java.lang.OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`java.lang.IllegalAssignmentError` when storing logic in this would violate the assignment rules.

LTMemory(long)

Signature

```
public
LTMemory(long size)
```

Create an `LTMemory` of the given size. This constructor is equivalent to `LTMemory(size, size)`

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is less than zero.

`java.lang.OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

LTMemory(long, Runnable)

Signature

```
public
LTMemory(long size,
         Runnable logic)
```

Create an `LTMemory` of the given size. This constructor is equivalent to `LTMemory(size, size, logic)`.

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

`logic` The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LTMemory(long size)`⁶².

Throws

`IllegalArgumentException` when `size` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`javax.realtime.IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

LTMemory(SizeEstimator)

Signature

```
public
LTMemory(SizeEstimator size)
```

Create an `LTMemory` of the given size. This constructor is equivalent to `LTMemory(size, size)`.

Parameters

`size` An instance of `SizeEstimator`⁶³ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

LTMemory(SizeEstimator, Runnable)

Signature

```
public
LTMemory(SizeEstimator size,
         Runnable logic)
```

⁶²Section 15.3.3.2.1

⁶³Section 11.4.2.5

Create an LMemory of the given size.

Parameters

size An instance of `SizeEstimator`⁶⁴ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

logic The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LMemory(SizeEstimator initial)`⁶⁵.

Throws

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the LMemory object or for the backing memory.

`javax.realtime.IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

11.5.3.1.2 Methods

toString

Signature

```
public
java.lang.String toString()
```

Create a string representation of this object. The string is of the form (LMemory) Scoped memory # num where `num` uniquely identifies the LMemory area.

Returns

A string representing the value of `this`.

11.5.3.2 PhysicalMemoryFactory

Inheritance

⁶⁴Section 11.4.2.5

⁶⁵Section 15.3.3.2.1

```
java.lang.Object
  javax.realtime.memory.PhysicalMemoryFactory
```

Both associate memory ranges, in the form of [PhysicalMemoryRegion](#)⁶⁶ instances with physical memory characteristics in the form of [PhysicalMemoryCharacteristic](#)⁶⁷ instances, and create memory areas in those modules.

Each physical memory module can have more than one physical memory characteristic. A physical memory characteristic can apply to many physical memory modules. The range of physical addresses of modules shall not overlap. A memory that spans more than one physical memory module may not be create.

The `PhysicalMemoryFactory` determines the physical addresses from the modules and keeps a relation between instances of `PhysicalMemoryRegion` and Physical Memory Addresses. The range of physical addresses of modules shall not overlap. A created memory are may not span more than one physical memory module. To find a memory range that supports PMC A and PMC B uses set intersection modules(A) \$ cap\$ modules(B)

11.5.3.2.1 Constructors

PhysicalMemoryFactory

Signature

```
public
PhysicalMemoryFactory()
```

11.5.3.2.2 Methods

associate(PhysicalMemoryCharacteristic, PhysicalMemoryRegion)

Signature

⁶⁶Section [11.5.3.3](#)

⁶⁷Section [11.5.1.1](#)


```

public static
void associate(PhysicalMemoryCharacteristic name,
               PhysicalMemoryRegion module)
throws IllegalArgumentException,
       IllegalStateException

```

Associates a programmer-defined name with a physical address range.

Parameters

name is the physical memory characteristic. e.g STATIC_RAM.

module is the object representing a range of contiguous physical addresses

Throws

`IllegalArgumentException` when either name or module is null

`IllegalStateException` when module overlaps a previously associated `PhysicalMemoryRegion` instance.

associate(PhysicalMemoryCharacteristic, PhysicalMemoryRegion)

Signature

```

public static
void associate(javax.realtime.memory.PhysicalMemoryCharacteristic[] names,
               PhysicalMemoryRegion module)
throws IllegalArgumentException,
       IllegalStateException

```

Associates an array of programmer-defined names with a physical address range.

Parameters

names is the array of physical memory characteristics. e.g STATIC_RAM.

module is the object representing a range of contiguous physical addresses

Throws

`IllegalArgumentException` when either names or module is null

`IllegalStateException` when module overlaps a previously associated `PhysicalMemoryRegion` instance.

associate(PhysicalMemoryCharacteristic, PhysicalMemoryRegion)

Signature

```

public static
void associate(PhysicalMemoryCharacteristic name,
               javax.realtime.memory.PhysicalMemoryRegion[] modules)
throws IllegalArgumentException,
       IllegalStateException

```

Associates a programmer-defined name with an array of physical address ranges.

Parameters

name is the physical memory characteristic. e.g STATIC_RAM.

modules is an array of objects each representing a range of contiguous physical addresses

Throws

IllegalArgumentException when either name or modules is null

IllegalStateException when module overlaps a previously associated PhysicalMemoryRegion instance.

createStackedMemory(PhysicalMemorySelector, long, long, Runnable)

Signature

```

public
javax.realtime.memory.StackedMemory createStackedMemory(javax.realtime.memory.PhysicalMemoryRegion selector,
                                                         long scopeSize,
                                                         long backingSize,
                                                         Runnable logic)

throws SecurityException,
       SizeOutOfBoundsException,
       UnsupportedPhysicalMemoryException,
       MemoryTypeConflictException,
       IllegalArgumentException

```

Instantiate a [StackedMemory](#)⁶⁸ object in a [PhysicalMemoryRegion](#)⁶⁹ matching the [PhysicalMemoryCharacteristic](#)⁷⁰ in selector and then with virtual memory parameters of selector applied.

Parameters

selector to use to choose the memory module and set the virtual mapping

scopeSize is the size of the scope to be created

⁶⁸Section [11.5.3.7](#)

⁶⁹Section [11.5.3.3](#)

⁷⁰Section [11.5.1.1](#)

`backingSize` is the size of the backing store to take out of the selected module
`logic` the logic to execute on entry (may be `null`)

Throws

`SecurityException` when the application does not have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that `size` extends beyond a physically addressable memory module.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryCharacteristic`⁷¹ has been registered with this `PhysicalMemoryFactory`.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

`IllegalArgumentException` when `scopeSize` or `backingSize` is less than zero.

Returns

the new memory area

createPinnableMemory(PhysicalMemorySelector, long, Runnable)

Signature

```
public
javax.realtime.memory.PinnableMemory createPinnableMemory(javax.realtime.memory
                                                         long size,
                                                         Runnable logic)

throws SecurityException,
       SizeOutOfBoundsException,
       UnsupportedPhysicalMemoryException,
       MemoryTypeConflictException,
       IllegalArgumentException
```

Instantiate a `PinnableMemory`⁷² object in a `PhysicalMemoryRegion`⁷³ matching the `PhysicalMemoryCharacteristic`⁷⁴ in `selector` and then with virtual memory parameters of `selector` applied.

⁷¹Section 11.5.1.1

⁷²Section 11.5.3.5

⁷³Section 11.5.3.3

⁷⁴Section 11.5.1.1

Parameters

selector to use to choose the memory module and set the virtual mapping

size is the size of memory to be taken out of the selected module

logic the logic to execute on entry (may be null)

Throws

SecurityException when the application does not have permissions to access physical memory or the given range of memory.

SizeOutOfBoundsException when the implementation detects that **size** extends beyond a physically addressable memory module.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryCharacteristic**⁷⁵ has been registered with this **PhysicalMemoryFactory**.

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is less than zero.

Returns

the new memory area

createImmortalMemory(PhysicalMemorySelector, long, Runnable)

Signature

```
public
javax.realtime.ImmortalMemory createImmortalMemory(javax.realtime.memory.PhysicalMemorySelector selector,
                                                    long size,
                                                    Runnable logic)

throws SecurityException,
       SizeOutOfBoundsException,
       UnsupportedPhysicalMemoryException,
       MemoryTypeConflictException,
       IllegalArgumentException
```

Instantiate a **ImmortalMemory**⁷⁶ object in a **PhysicalMemoryRegion**⁷⁷ matching the **PhysicalMemoryCharacteristic**⁷⁸ in **selector** and then with virtual memory

⁷⁵Section 11.5.1.1

⁷⁶Section 11.4.2.2

⁷⁷Section 11.5.3.3

⁷⁸Section 11.5.1.1

parameters of `selector` applied.

Parameters

`selector` to use to choose the memory module and set the virtual mapping

`size` is the size of memory to be taken out of the selected module

`logic` the logic to execute on entry (may be `null`)

Throws

`SecurityException` when the application does not have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that `size` extends beyond a physically addressable memory module.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryCharacteristic`⁷⁹ has been registered with this `PhysicalMemoryFactory`.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

`IllegalArgumentException` when `size` is less than zero.

Returns

the new memory area

11.5.3.3 PhysicalMemoryRegion

Inheritance

`java.lang.Object`

`javax.realtime.memory.PhysicalMemoryRegion`

Enable an application to define a range of physical memory addresses.

11.5.3.3.1 Constructors

PhysicalMemoryRegion(long, long)

Signature

⁷⁹Section 11.5.1.1

```
public  
PhysicalMemoryRegion(long base,  
                      long length)
```

Creates an instance representing a range of contiguous physical memory.

Parameters

base is a physical address

length is size of contiguous memory from that base

Throws

IllegalArgumentException when length is less than or equal to 0, or when base is less than 0 or when this module overlaps with another memory module.

SizeOutOfBounds when base + length is greater than the physical address range of the processor

11.5.3.3.2 Methods

getBase

Signature

```
public  
long getBase()
```

Gets the base address of the contiguous memory represented by this.

Returns

the base address

getLength

Signature

```
public  
long getLength()
```

Gets the length of the contiguous memory represented by this.

Returns

the length

11.5.3.4 PhysicalMemorySelector

Inheritance

java.lang.Object

javax.realtime.memory.PhysicalMemorySelector

Provides both characteristics both for physical memory, used to select a memory range from a memory module, and for virtual memory to be used for setting the characteristics of the mapped pages.

11.5.3.4.1 Constructors

PhysicalMemorySelector(PhysicalMemoryCharacteristic, VirtualMemoryCharacteristic, CachingBehavior, PagingBehavior)

Signature

public

```
PhysicalMemorySelector(javax.realtime.memory.PhysicalMemoryCharacteristic[] pmc,  
                        javax.realtime.memory.VirtualMemoryCharacteristic[] vmc,  
                        PhysicalMemorySelector.CachingBehavior caching,  
                        PhysicalMemorySelector.PagingBehavior paging)
```

11.5.3.4.2 Methods

getSupportedCachingBehavior

Signature

public static

```
javax.realtime.memory.PhysicalMemorySelector.CachingBehavior[] getSupportedCach
```

Get the caching behaviors that are supported by this JVM

Returns

an array of the supported caching behaviors.

getSupportedPagingBehavior

Signature

```
public static  
    javax.realtime.memory.PhysicalMemorySelector.PagingBehavior[] getSupportedPagingBehaviors()
```

Get the paging behaviors that are supported by this JVM

Returns

an array of the supported paging behaviors.

getPhysicalMemoryCharacteristics

Signature

```
public  
    javax.realtime.memory.PhysicalMemoryCharacteristic[] getPhysicalMemoryCharacteristics()
```

A getter for the PhysicalMemoryCharacteristic list to be requested

Returns

the PhysicalMemoryCharacteristic list

getVirtualMemoryCharateristics

Signature

```
public  
    javax.realtime.memory.VirtualMemoryCharacteristic[] getVirtualMemoryCharateristics()
```

A getter for the VirtualMemoryCharacteristic list to be requested

Returns

the VirtualMemoryCharacteristic list

getCachingBehavior

Signature

```
public  
    javax.realtime.memory.PhysicalMemorySelector.CachingBehavior getCachingBehavior()
```


A getter for the `CachingBehavior` to be requested

Returns

the `CachingBehavior`

getPagingPagingBehavior

Signature

`public`

`javax.realtime.memory.PhysicalMemorySelector.PagingBehavior getPagingPagingBeha`

A getter for the `PagingBehavior` to be requested

Returns

the `PagingBehavior`

11.5.3.5 PinnableMemory

Inheritance

`java.lang.Object`

`javax.realtime.MemoryArea`

`javax.realtime.memory.ScopedMemory`

`javax.realtime.memory.PinnableMemory`

This class is for passing information between different threads as in the producer consumer pattern. One thread can enter an empty `PinnableMemory`, allocate some data structure, put a reference in the portal, pin the scope, exit it, and then pass it to another thread for further processing or consumption. Once the last thread is done, the memory can be unpinned, causing its contents to be freed.

11.5.3.5.1 Constructors

PinnableMemory(long)

Signature

`public`

`PinnableMemory(long size)`

Create a scope of fixed size.

Parameters

size is the number of bytes in the memory area.

PinnableMemory(SizeEstimator)

Signature

```
public
PinnableMemory(SizeEstimator size)
```

Create a scope of fixed size.

Parameters

size is an estimator for determining the number of bytes in the memory area.

11.5.3.5.2 Methods

pin

Signature

```
public
void pin()
```

Prevent the contents from being freed.

unpin

Signature

```
public
void unpin()
```

Allow the contents to be freed the next time no [javax.realtime.Schedulable](#)⁸⁰ or [javax.realtime.AsyncBaseEvent](#)⁸¹ is active withing the scope.

⁸⁰Section [6.4.1.3](#)

⁸¹Section [8.4.3.2](#)

isPinned

Signature

```
public  
boolean isPinned()
```

Determin whether the scope may be cleared on last exit.

Returns

true when yes, otherwise false.

getPinCount

Signature

```
public  
int getPinCount()
```

Find out how many times the scope has been pinned, but not unpinned.

Returns

the number of outstanding pins.

joinPinned

Signature

```
public  
void joinPinned()  
throws InterruptedException
```

Wait until the scope has been cleared and then pin it.

joinPinned(HighResolutionTime)

Signature

```
public  
void joinPinned(javax.realtime.HighResolutionTime< T> limit)  
throws InterruptedException
```

Wait until the scope has been cleared and then pin it, within a specified time frame.

Parameters

limit is the maximum time to wait

joinPinnedAndEnter(Runnable)

Signature

```
public
void joinPinnedAndEnter(Runnable logic)
throws InterruptedException,
    ScopedCycleException
```

Wait until the scope has been cleared and then pin it and enter it.

Parameters

`logic` is the logic to execute upon entry

joinPinnedAndEnter(Runnable, HighResolutionTime)

Signature

```
public
void joinPinnedAndEnter(Runnable logic,
                        javax.realtime.HighResolutionTime< T> limit)
throws InterruptedException,
    ScopedCycleException
```

Wait until the scope has been cleared and then pin it and enter it, within a specified time frame.

Parameters

`logic` is the logic to execute upon entry

`limit` is the maximum time to wait.

joinPinnedAndEnter

Signature

```
public
void joinPinnedAndEnter()
throws InterruptedException,
    IllegalThreadStateException,
    ThrowBoundaryError,
    ScopedCycleException,
    MemoryAccessError
```

Wait until the scope has been cleared and then pin it and enter it.

joinPinnedAndEnter(HighResolutionTime)

Signature

```
public
void joinPinnedAndEnter(javax.realtime.HighResolutionTime< T> limit)
throws InterruptedException,
    IllegalStateException,
    IllegalArgumentException,
    UnsupportedOperationException,
    ThrowBoundaryError,
    ScopedCycleException,
    MemoryAccessError
```

Wait until the scope has been cleared and then pin it and enter it, within a specified time frame.

Parameters

`limit` is the maximum time to wait.

11.5.3.6 ScopedMemory

Inheritance

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.memory.ScopedMemory
```

ScopedMemory is the abstract base class of all classes dealing with representations of memory spaces which have a limited lifetime. In general, objects allocated in scoped memory are freed when (and only when) no schedulable object has access to the objects in the scoped memory.

A **ScopedMemory** area is a connection to a particular region of memory and reflects the current status of that memory. The object does not necessarily contain direct references to the region of memory. That is implementation dependent.

When a **ScopedMemory** area is instantiated, the object itself is allocated from the current memory allocation context, but the memory space that object represents (it's backing store) is allocated from memory that is not otherwise directly visible to Java code; e.g., it might be allocated with the C `malloc` function. This backing store behaves effectively as if it were allocated when the associated scoped memory object is constructed and freed at that scoped memory object's finalization.

The `ScopedMemory.enter`⁸² method of `ScopedMemory` is one mechanism used to make a memory area the current allocation context. The other mechanism for activating a memory area is making it the initial memory area for a realtime thread or async event handler. Entry into the scope is accomplished, for example, by calling the

```
public void enter(Runnable logic)
```

where `logic` is a instance of `Runnable` whose `run()` method represents the entry point of the code that will run in the new scope. Exit from the scope occurs between the time the `runnable.run()` method completes and the time control returns from the `enter` method. By default, allocations of objects within `runnable.run()` are taken from the backing store of the `ScopedMemory`.

`ScopedMemory` is an abstract class, but all specified methods include implementations. The responsibilities of `MemoryArea`, `ScopedMemory` and the classes that extend `ScopedMemory` are not specified. Application code should not extend `ScopedMemory` without detailed knowledge of its implementation. since RTSJ 2.0

11.5.3.6.1 Constructors

ScopedMemory(long)

Signature

```
public
ScopedMemory(long size)
```

Create a new `ScopedMemory` area with the given parameters.

Parameters

`size` of the new `ScopedMemory` area in bytes.

Throws

`IllegalArgumentException` when `size` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(long, Runnable)

⁸²Section 15.3.3.11.2

Signature

```
public  
ScopedMemory(long size,  
              Runnable logic)
```

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area in bytes.

logic The `Runnable` to execute when this `ScopedMemory` is entered. When **logic** is `null`, this constructor is equivalent to constructing the memory area without a logic value.

Throws

`IllegalArgumentException` when **size** is less than zero.

`IllegalAssignmentError` when storing **logic** in **this** would violate the assignment rules.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(SizeEstimator)

Signature

```
public  
ScopedMemory(SizeEstimator size)
```

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area estimated by an instance of `SizeEstimator`⁸³.

Throws

`IllegalArgumentException` when **size** is `null`, or **size.getEstimate()** is negative.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(SizeEstimator, Runnable)

⁸³Section 11.4.2.5

Signature

```
public
ScopedMemory(SizeEstimator size,
              Runnable logic)
```

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area estimated by an instance of `SizeEstimator`⁸⁴.

logic The logic which will use the memory represented by `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to constructing the memory area without a logic value.

Throws

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is negative.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

11.5.3.6.2 Methods

enter*Signature*

```
public
void enter()
```

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the instance of `Runnable` given in the constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`⁸⁵) or the `enter` method exits.

Throws

⁸⁴Section 11.4.2.5

⁸⁵Section 15.3.3.11.2

`ScopedCycleException` when this invocation would break the single parent rule.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in **this** scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`⁸⁶, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`⁸⁷ is allocated in the current allocation context and contains information about the exception it replaces.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`IllegalArgumentException`

`MemoryAccessError`

enter(Runnable)

Signature

```
public
void enter(Runnable logic)
```

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the given `Runnable`. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`⁸⁸) or the `enter` method exits.

Parameters

`logic`

Throws

`ScopedCycleException` when this invocation would break the single parent rule.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in **this** scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`⁸⁹, so

⁸⁶Section 14.3.3.3

⁸⁷Section 14.3.3.7

⁸⁸Section 15.3.3.11.2

⁸⁹Section 14.3.3.3

the JVM cannot be permitted to deliver the exception. The **ThrowBoundaryError**⁹⁰ is allocated in the current allocation context and contains information about the exception it replaces.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

IllegalArgumentException

enter(Supplier)

Signature

```
public
T enter(java.util.function.Supplier< T> logic)
```

Same as **enter(Runnable)**⁹¹ except that the executed method is called **get** and an object is returned.

Parameters

logic the object who's get method will be executed.

Returns

a result from the computation.

enter(BooleanSupplier)

Signature

```
public
boolean enter(BooleanSupplier logic)
```

Same as **enter(Runnable)**⁹² except that the executed method is called **get** and a **boolean** is returned.

Parameters

logic the object who's get method will be executed.

Returns

a result from the computation.

⁹⁰Section 14.3.3.7

⁹¹Section 15.3.3.11.2

⁹²Section 15.3.3.11.2

enter(IntSupplier)

Signature

```
public  
int enter(IntSupplier logic)
```

Same as `enter(Runnable)`⁹³ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(LongSupplier)

Signature

```
public  
long enter(LongSupplier logic)
```

Same as `enter(Runnable)`⁹⁴ except that the executed method is called `get` and a `long` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(DoubleSupplier)

Signature

```
public  
double enter(DoubleSupplier logic)
```

Same as `enter(Runnable)`⁹⁵ except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's `get` method will be executed.

⁹³Section 15.3.3.11.2

⁹⁴Section 15.3.3.11.2

⁹⁵Section 15.3.3.11.2

Returns

a result from the computation.

executeInArea(Runnable)*Signature*

```
public  
void executeInArea(Runnable logic)
```

Execute the run method from the `logic` parameter using this memory area as the current allocation context. This method behaves as if it moves the allocation context down the scope stack to the occurrence of `this`.

Parameters

`logic` The runnable object whose `run()` method should be executed.

Throws

`IllegalThreadStateException` when the caller is a Java thread.

`InaccessibleAreaException` when the memory area is not in the schedulable's scope stack.

`IllegalArgumentException` when the caller is a schedulable and `logic` is null.

executeInArea(Supplier)*Signature*

```
public  
T executeInArea(java.util.function.Supplier< T> logic)
```

Same as `executeInArea(Runnable)`⁹⁶ except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(BooleanSupplier)*Signature*

⁹⁶Section 15.3.3.11.2

```
public
boolean executeInArea(BooleanSupplier logic)
```

Same as `executeInArea(Runnable)`⁹⁷ except that the executed method is called `get` and a `boolean` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(IntSupplier)

Signature

```
public
int executeInArea(IntSupplier logic)
```

Same as `executeInArea(Runnable)`⁹⁸ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(LongSupplier)

Signature

```
public
long executeInArea(LongSupplier logic)
```

Same as `executeInArea(Runnable)`⁹⁹ except that the executed method is called `get` and a `long` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

⁹⁷Section [15.3.3.11.2](#)

⁹⁸Section [15.3.3.11.2](#)

⁹⁹Section [15.3.3.11.2](#)

executeInArea(DoubleSupplier)

Signature

```
public  
double executeInArea(DoubleSupplier logic)
```

Same as **executeInArea(Runnable)**¹⁰⁰ except that the executed method is called **get** and a **double** is returned.

Parameters

logic the object who's get method will be executed.

Returns

a result from the computation.

getPortal

Signature

```
public  
java.lang.Object getPortal()
```

Return a reference to the portal object in this instance of **ScopedMemory**.

Assignment rules are enforced on the value returned by **getPortal** as if the return value were first stored in an object allocated in the current allocation context, then moved to its final destination.

Throws

IllegalAssignmentError when a reference to the portal object cannot be stored in the caller's allocation context; that is, when **this** is "inner" relative to the current allocation context or not on the caller's scope stack.

IllegalThreadStateException when the caller is a Java thread.

Returns

A reference to the portal object or **null** when there is no portal object. The portal value is always set to **null** when the contents of the memory are deleted.

getReferenceCount

Signature

```
public  
int getReferenceCount()
```

¹⁰⁰Section 15.3.3.11.2

Returns the reference count of this `ScopedMemory`.

Note: A reference count of 0 reliably means that the scope is not referenced, but other reference counts are subject to artifacts of lazy/eager maintenance by the implementation.

Returns

The reference count of this `ScopedMemory`.

join

Signature

```
public
void join()
throws InterruptedException
```

Wait until the reference count of this `ScopedMemory` goes down to zero. Return immediately when the memory is unreferenced.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁰¹ or `AsynchronouslyInterruptedException.fire()`¹⁰² while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread.

join(HighResolutionTime)

Signature

```
public
void join(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException
```

Wait at most until the time designated by the `time` parameter for the reference count of this `ScopedMemory` to drop to zero. Return immediately when the memory area is unreferenced.

Since the time is expressed as a `HighResolutionTime`¹⁰³, this method is an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the delay is the amount of

¹⁰¹Section 5.3.2.2.2

¹⁰²Section 8.4.2.1.2

¹⁰³Section 9.4.1.2

time given by `time`, and measured by its associated clock. When absolute, then the delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `join` returns immediately.

Parameters

time When this time is an absolute time, the wait is bounded by that point in time. When the time is a relative time (or a member of the `RationalTime` subclass of `RelativeTime`) the wait is bounded by a the specified interval from some time between the time `join` is called and the time it starts waiting for the reference count to reach zero.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁰⁴ or `AsynchronouslyInterruptedException.fire()`¹⁰⁵ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread.

`IllegalArgumentException` when the caller is a schedulable and `time` is `null`.

`UnsupportedOperationException` when the wait operation is not supported using the clock associated with `time`.

joinAndEnter

Signature

```
public
void joinAndEnter()
throws InterruptedException
```

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, then enter the `ScopedMemory` and execute the `run` method from `logic` passed in the constructor. When no instance of `Runnable` was passed to the memory area's constructor, the method throws `IllegalArgumentException` immediately.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although `joinAndEnter` guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference

¹⁰⁴Section 5.3.2.2.2

¹⁰⁵Section 8.4.2.1.2

count will remain one for any length of time. A subsequent `enter` could raise the reference count to two.

Throws

InterruptedException When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁰⁶ or `AsynchronouslyInterruptedException.fire()`¹⁰⁷ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in this scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`¹⁰⁸, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹⁰⁹ is allocated in the current allocation context and contains information about the exception it replaces.

ScopedCycleException when this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable and no non-null logic value was supplied to the memory area's constructor.

MemoryAccessError when caller is a non-heap schedulable and this memory area's logic value is allocated in heap memory.

joinAndEnter(HighResolutionTime)

Signature

```
public
void joinAndEnter(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException
```

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, or for the current time to reach the designated time, then enter the

¹⁰⁶Section 5.3.2.2.2

¹⁰⁷Section 8.4.2.1.2

¹⁰⁸Section 14.3.3.3

¹⁰⁹Section 14.3.3.7

ScopedMemory and execute the **run** method from **Runnable** object passed to the constructor. When no instance of **Runnable** was passed to the memory area's constructor, the method throws **IllegalArgumentException** immediately. *

When multiple threads are waiting in **joinAndEnter** family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Since the time is expressed as a **HighResolutionTime**¹¹⁰, this method has an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with **time**. The delay time may be relative or absolute. When relative, then the calling thread is blocked for at most the amount of time given by **time**, and measured by its associated clock. When absolute, then the time delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to **joinAndEnter** behaves effectively like **enter**¹¹¹.

Note that expiration of **time** may cause control to enter the memory area before its reference count has gone to zero.

Parameters

time The time that bounds the wait.

Throws

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in **this** scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an **IllegalAssignmentError**¹¹², so the JVM cannot be permitted to deliver the exception. The **ThrowBoundaryError**¹¹³ is allocated in the current allocation context and contains information about the exception it replaces.

InterruptedException When this schedulable is interrupted by **RealtimeThread.interrupt()**¹¹⁴ or **AsynchronouslyInterruptedException.fire()**¹¹⁵ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

ScopedCycleException when the caller is a schedulable and this invocation

¹¹⁰Section 9.4.1.2

¹¹¹Section 15.3.3.11.2

¹¹²Section 14.3.3.3

¹¹³Section 14.3.3.7

¹¹⁴Section 5.3.2.2.2

¹¹⁵Section 8.4.2.1.2

would break the single parent rule.

IllegalArgumentException when the caller is a schedulable, and **time** is **null** or no non-null **logic** value was supplied to the memory area's constructor.

UnsupportedOperationException when the wait operation is not supported using the clock associated with **time**.

MemoryAccessError when caller is a no-heap schedulable and this memory area's **logic** value is allocated in heap memory.

joinAndEnter(Runnable)

Signature

```
public  
void joinAndEnter(Runnable logic)  
throws InterruptedException
```

In the error-free case, **joinAndEnter** combines **join();enter();** such that no **enter()** from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this **ScopedMemory** to reach zero, then enter the **ScopedMemory** and execute the **run** method from **logic**

When **logic** is **null**, throw **IllegalArgumentException** immediately.

When multiple threads are waiting in **joinAndEnter** family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although **joinAndEnter** guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference count will remain one for any length of time. A subsequent **enter** could raise the reference count to two.

Parameters

logic The **Runnable** object which contains the code to execute.

Throws

InterruptedException When this schedulable is interrupted by **RealtimeThread.interrupt()**¹¹⁶ or **AsynchronouslyInterruptedException.fire()**¹¹⁷ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered

¹¹⁶Section 5.3.2.2.2

¹¹⁷Section 8.4.2.1.2

finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in this scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an **IllegalAssignmentError**¹¹⁸, so the JVM cannot be permitted to deliver the exception. The **ThrowBoundaryError**¹¹⁹ is allocated in the current allocation context and contains information about the exception it replaces.

ScopedCycleException when this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable and logic is null.

joinAndEnter(Supplier)

Signature

```
public
T joinAndEnter(java.util.function.Supplier< T> logic)
```

Same as **joinAndEnter(Runnable)**¹²⁰ except that the executed method is called **get** and an object is returned.

Parameters

logic the object who's get method will be executed.

Returns

a result from the computation.

joinAndEnter(BooleanSupplier)

Signature

```
public
boolean joinAndEnter(BooleanSupplier logic)
```

Same as **joinAndEnter(Runnable)**¹²¹ except that the executed method is called **get** and a boolean is returned.

Parameters

¹¹⁸Section 14.3.3.3

¹¹⁹Section 14.3.3.7

¹²⁰Section 15.3.3.11.2

¹²¹Section 15.3.3.11.2

logic the object who's get method will be executed.

Returns

a result from the computation.

joinAndEnter(IntSupplier)

Signature

```
public  
int joinAndEnter(IntSupplier logic)
```

Same as `joinAndEnter(Runnable)`¹²² except that the executed method is called `get` and an `int` is returned.

Parameters

logic the object who's get method will be executed.

Returns

a result from the computation.

joinAndEnter(LongSupplier)

Signature

```
public  
long joinAndEnter(LongSupplier logic)
```

Same as `joinAndEnter(Runnable)`¹²³ except that the executed method is called `get` and a `long` is returned.

Parameters

logic the object who's get method will be executed.

Returns

a result from the computation.

joinAndEnter(DoubleSupplier)

Signature

```
public  
double joinAndEnter(DoubleSupplier logic)
```

¹²²Section [15.3.3.11.2](#)

¹²³Section [15.3.3.11.2](#)

Same as `joinAndEnter(Runnable)`¹²⁴ except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(Runnable, HighResolutionTime)

Signature

```
public
void joinAndEnter(Runnable logic,
                  javax.realtime.HighResolutionTime<?> time)
throws InterruptedException
```

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, or for the current time to reach the designated time, then enter the `ScopedMemory` and execute the `run` method from `logic`.

Since the time is expressed as a `HighResolutionTime`¹²⁵, this method is an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the delay is the amount of time given by `time`, and measured by its associated clock. When absolute, then the delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `joinAndEnter` behaves effectively like `enter(Runnable)`¹²⁶.

Throws `IllegalArgumentException` immediately when `logic` is `null`.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that expiration of `time` may cause control to enter the memory area before its reference count has gone to zero.

Parameters

`logic` The `Runnable` object which contains the code to execute.

`time` The time that bounds the wait.

¹²⁴Section 15.3.3.11.2

¹²⁵Section 9.4.1.2

¹²⁶Section 15.3.3.11.2

Throws

InterruptedException When this schedulable is interrupted by `RealtimeThread.interrupt()`¹²⁷ or `AsynchronouslyInterruptedException.fire()`¹²⁸ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in this scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`¹²⁹, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹³⁰ is allocated in the current allocation context and contains information about the exception it replaces.

ScopedCycleException when the caller is a schedulable and this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable and `time` or `logic` is null.

UnsupportedOperationException when the wait operation is not supported using the clock associated with `time`.

joinAndEnter(Supplier, HighResolutionTime)*Signature*

```
public
P joinAndEnter(java.util.function.Supplier< P> logic,
               javax.realtime.HighResolutionTime<?> time)
```

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³¹ except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

¹²⁷Section 5.3.2.2.2

¹²⁸Section 8.4.2.1.2

¹²⁹Section 14.3.3.3

¹³⁰Section 14.3.3.7

¹³¹Section 15.3.3.11.2

joinAndEnter(BooleanSupplier, HighResolutionTime)

Signature

```
public
boolean joinAndEnter(BooleanSupplier logic,
                     javax.realtime.HighResolutionTime<?> time)
```

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³² except that the executed method is called `get` and a `boolean` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(IntSupplier, HighResolutionTime)

Signature

```
public
int joinAndEnter(IntSupplier logic,
                 javax.realtime.HighResolutionTime<?> time)
```

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³³ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(LongSupplier, HighResolutionTime)

Signature

```
public
long joinAndEnter(LongSupplier logic,
                  javax.realtime.HighResolutionTime<?> time)
```

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³⁴ except that the executed method is called `get` and a `long` is returned.

¹³²Section 15.3.3.11.2

¹³³Section 15.3.3.11.2

¹³⁴Section 15.3.3.11.2

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

joinAndEnter(DoubleSupplier, HighResolutionTime)*Signature*

```
public
double joinAndEnter(DoubleSupplier logic,
                    javax.realtime.HighResolutionTime<?> time)
```

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³⁵ except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

getParent*Signature*

```
public
javax.realtime.MemoryArea getParent()
```

Return a reference to this scopes parent scope (e.g., its parent in the single-parent-rule tree).

Returns

- a reference to the next outer scoped memory region on the caller's scope stack.
 - When there is no outer scoped memory and the primordial parent is heap memory, return a reference to `this`.
 - When there is no outer scoped memory and the primordial parent is immortal, or when `this` is unreferenced and unpinned, return `null`

Problem. The single-parent tree is RTT-independent except for the primordial scope. The type of the primordial scope is RTT-dependent. What should we do about that? When called from a RTT that has entered `this`, the above rules make some sense, but what if the caller has not even entered the scope, should we throw an exception? Or just return `null`? I think the right solution is to

¹³⁵Section 15.3.3.11.2

return *this* whatever the type of the primordial scope. The app can then know that *null* means the scope is not pinned and not referenced, and *this* means the parent is either heap or immortal. At that point, the app can learn what it wants to know by just finding what memory area contains the scope object.

visitNestedMemory(MemoryAreaVisitor)

Signature

```
public
R visitNestedMemory(javax.realtime.MemoryAreaVisitor< R> visitor)
```

Throws

IllegalArgumentException when visitor is null.

newArray(Class, int)

Signature

```
public
java.lang.Object newArray(java.lang.Class<?> type,
                           int number)
```

Allocate an array of the given type in this memory area. This method may be concurrently used by multiple threads.

Parameters

type
number

Throws

IllegalArgumentException
javax.realtime.StaticOutOfMemoryError
IllegalThreadStateException when the caller is a Java thread.
InaccessibleAreaException when the memory area is not in the schedulable's scope stack.

Returns

newInstance(Class)

Signature

```
public
T newInstance(java.lang.Class< T> type)
throws IllegalAccessException,
    InstantiationException
```

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

type

Throws

IllegalAccessException

IllegalArgumentException

ExceptionInInitializerError

javax.realtime.StaticOutOfMemoryError

InstantiationException

IllegalThreadStateException when the caller is a Java thread.

InaccessibleAreaException when the memory area is not in the schedulable's scope stack.

Returns

newInstance(Constructor, Object)

Signature

```
public
T newInstance(java.lang.reflect.Constructor< T> c,
              java.lang.Object[] args)
throws IllegalAccessException,
    InstantiationException,
    InvocationTargetException
```

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

c T

args

Throws

IllegalAccessException

InstantiationException

`javax.realtime.StaticOutOfMemoryError`
`IllegalArgumentException`
`IllegalThreadStateException` when the caller is a Java thread.
`InvocationTargetException`
`InaccessibleAreaException` when the memory area is not in the schedulable's scope stack.

Returns

setPortal(Object)

Signature

```
public  
void setPortal(Object object)
```

Sets the *portal* object of the memory area represented by this instance of `ScopedMemory` to the given object. The object must have been allocated in this `ScopedMemory` instance.

Parameters

object The object which will become the portal for this. When `null` the previous portal object remains the portal object for this or when there was no previous portal object then there is still no portal object for **this**.

Throws

`IllegalThreadStateException` when the caller is a Java Thread.
`IllegalAssignmentError` when the caller is a schedulable, and **object** is not allocated in this scoped memory instance and not `null`.
`InaccessibleAreaException` when the caller is a schedulable, **this** memory area is not in the caller's scope stack and **object** is not `null`.

toString

Signature

```
public  
java.lang.String toString()
```

Returns a user-friendly representation of this `ScopedMemory` of the form "`ScopedMemory#<num>`" where `<num>` is a number that uniquely identifies this scoped memory area.

Returns

The string representation

11.5.3.7 **StackedMemory**

Inheritance

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.memory.ScopedMemory
      javax.realtime.memory.StackedMemory
```

StackedMemory implements a scoped memory allocation area and backing store management system. It is designed to allow for safe, fragmentation-free management of scoped allocation with certain strong guarantees provided by the virtual machine and runtime libraries.

Each **StackedMemory** instance represents a single object allocation area and additional memory associated with it in the form of a *backing store*. The backing store associated with a **StackedMemory** is a fixed-size memory area allocated at or before instantiation of the **StackedMemory**. The object allocation area is taken from the associated backing store, and the backing store may be further subdivided into additional **StackedMemory** allocation areas or backing stores by instantiating additional **StackedMemory** objects.

When a **StackedMemory** is created with a backing store, the backing store may be taken from a notional global backing store, in which case it is effectively immortal, or it may be taken from the enclosing **StackedMemory**'s backing store when the scope in which it is created is also a **StackedMemory**, in which case it is returned to its enclosing scope's backing store when the object is finalized. Implementations are not required to return the space occupied by backing stores taken from the global backing store when their associated **StackedMemory** object is finalized.

These backing store semantics divide instances of **StackedMemory** into two categories:

- *Host* — this denotes a **StackedMemory** with an object allocation area created in a new backing store, allocated either from the global store or from a parent **StackedMemory**'s backing store.
- *guest* — this in turn indicates a **StackedMemory** with an object allocation area taken directly from a parent **StackedMemory**'s backing store without creating a sub-store.

In addition, there is one distinguished status for **StackedMemory** objects, *root*. A *root* **StackedMemory** is a *host* **StackedMemory** created with a backing store drawn directly from the global backing store, created in an allocation context of some type other than **StackedMemory**.

Allocations from a **StackedMemory** object allocation area are guaranteed to run in time linear in the size of the allocation. All memory for the backing store must be reserved at object construction time.

StackedMemory memory areas have two additional stacking constraints in addition to the single parent rule, designed to enable fragmentation-free manipulation:

- A **StackedMemory** that is created when another **StackedMemory** is the current allocation context can only be entered from the same allocation context in which it was created.
- A guest **StackedMemory** cannot be created from a **StackedMemory** that currently has another child area that is also a guest **StackedMemory**. (That is, a **StackedMemory** can have at most one direct child that is a guest **StackedMemory**.)

The **StackedMemory** constructor semantics also enforce the property that a **StackedMemory** cannot be created from another **StackedMemory** allocation context unless it is allocated from that context's backing store as either a host or guest area.

The backing store of a **StackedMemory** behaves as if any **StackedMemory** object allocation areas are at the “bottom” of the backing store, while the backing stores for enclosed **StackedMemory** areas are taken from the “top” of the backing store.

There may be an implementation-specific memory overhead for creating a backing store of a given size. This means that creating a **StackedMemory** with a backing store of exactly the remaining available backing store of the current **StackedMemory** may fail with an `javax.realtime.StaticOutOfMemoryError`. This overhead must be bounded by a constant.

11.5.3.7.1 Constructors

StackedMemory(long, long)

Signature

```
public
    StackedMemory(long scopeSize,
                  long backingSize)
```

Create a host **StackedMemory** with an object allocation area and backing store of the specified sizes. The backing store is allocated from the currently active memory area when it is also a **StackedMemory**, and the global backing store otherwise. The object allocation area is allocated from the backing store.

Parameters

scopeSize Size of the allocation area

backingSize Size of the total backing store

Throws

IllegalArgumentException when either **scopeSize** or **backingSize** is less than zero, or when **scopeSize** is too large to be allocated from a backing store of size **backingSize**.

java.lang.OutOfMemoryError when there is insufficient memory available to reserve the requested backing store.

StackedMemory(long, long, Runnable)*Signature*

```
public
StackedMemory(long scopeSize,
               long backingSize,
               Runnable logic)
```

Create a host **StackedMemory** with an object allocation area and backing store of the specified sizes, bound to the specified **Runnable**. The backing store is allocated from the currently active memory area when it is also a **StackedMemory**, and the global backing store otherwise. The object allocation area is allocated from the backing store.

Parameters

scopeSize Size of the allocation area

backingSize Size of the total backing store

logic **Runnable** to be entered using **this** as its current memory area when **enter()**¹³⁶ is called.

Throws

IllegalArgumentException when either **scopeSize** or **backingSize** is less than zero, or when **scopeSize** is too large to be allocated from a backing store of size **backingSize**.

java.lang.OutOfMemoryError when there is insufficient memory available to reserve the requested backing store.

StackedMemory(SizeEstimator, SizeEstimator)

¹³⁶Section 11.5.3.7.2

Signature

```
public
StackedMemory(SizeEstimator scopeSize,
               SizeEstimator backingSize)
```

Create a host **StackedMemory** with an object allocation area and backing store of the sizes estimated by the specified **SizeEstimators**. The backing store is allocated from the currently active memory area when it is also a **StackedMemory**, and the global backing store otherwise. The object allocation area is allocated from the backing store.

Parameters

scopeSize **SizeEstimator** indicating the size of the object allocation area

backingSize **SizeEstimator** indicating the size of the total backing store

Throws

IllegalArgumentException when either **scopeSize** or **backingSize** is less than zero, or when **scopeSize** is too large to be allocated from a backing store of size **backingSize**.

javax.realtime.StaticOutOfMemoryError when there is insufficient memory available to reserve the requested backing store.

StackedMemory(SizeEstimator, SizeEstimator, Runnable)*Signature*

```
public
StackedMemory(SizeEstimator scopeSize,
               SizeEstimator backingSize,
               Runnable logic)
```

Create a host **StackedMemory** with an object allocation area and backing store of the sizes estimated by the specified **SizeEstimators**, bound to the specified **Runnable**. The backing store is allocated from the currently active memory area when it is also a **StackedMemory**, and the global backing store otherwise. The object allocation area is allocated from the backing store.

Parameters

scopeSize **SizeEstimator** indicating the size of the object allocation area

backingSize **SizeEstimator** indicating the size of the total backing store

logic `Runnable` to be entered using `this` as its current memory area when `enter()`¹³⁷ is called.

Throws

`IllegalArgumentException` when either `scopeSize` or `backingSize` is less than zero, or when `scopeSize` is too large to be allocated from a backing store of size `backingSize`.

`java.lang.OutOfMemoryError` when there is insufficient memory available to reserve the requested backing store.

`StackedMemory(long)`

Signature

```
public  
StackedMemory(long scopeSize)
```

Create a guest `StackedMemory` with an object allocation area of the specified size. The object allocation area is drawn from the same backing store as the parent scope's object allocation area. The parent scope must be a `StackedMemory`.

Parameters

`scopeSize` Size of the allocation area

Throws

`IllegalStateException` when the parent memory area is not a `StackedMemory`, or when the parent `StackedMemory` already has a child that is also a guest `StackedMemory`.

`IllegalArgumentException` when `scopeSize` is less than zero.

`java.lang.OutOfMemoryError` when there is insufficient memory available in the backing store of the parent `StackedMemory`'s object allocation area to reserve the requested object allocation area.

`StackedMemory(SizeEstimator)`

Signature

```
public  
StackedMemory(SizeEstimator scopeSize)
```

¹³⁷Section 11.5.3.7.2

Create a guest **StackedMemory** with an object allocation area of the size estimated by the specified **SizeEstimator**. The object allocation area is drawn from the same backing store as the parent scope's object allocation area. The parent scope must be a **StackedMemory**.

Parameters

scopeSize **SizeEstimator** indicating the size of the object allocation area

Throws

IllegalStateException when the parent memory area is not a **StackedMemory**, or when the parent **StackedMemory** already has a child that is also a guest **StackedMemory**.

IllegalArgumentException when **scopeSize** is less than zero.

javax.realtime.StaticOutOfMemoryError when there is insufficient memory available in the backing store of the parent **StackedMemory**'s object allocation area to reserve the requested object allocation area.

StackedMemory(long, Runnable)

Signature

```
public
StackedMemory(long scopeSize,
               Runnable logic)
```

Create a guest **StackedMemory** with an object allocation area of the specified size, bound to the specified **Runnable**. The object allocation area is drawn from the same backing store as the parent scope's object allocation area. The parent scope must be a **StackedMemory**.

Parameters

scopeSize Size of the allocation area

logic **Runnable** to be entered using **this** as its current memory area when **enter()**¹³⁸ is called.

Throws

IllegalStateException when the parent memory area is not a **StackedMemory**, or when the parent **StackedMemory** already has a child that is also a guest **StackedMemory**.

IllegalArgumentException when **scopeSize** is less than zero.

javax.realtime.StaticOutOfMemoryError when there is insufficient memory available in the backing store of the parent **StackedMemory**'s object allo-

¹³⁸Section 11.5.3.7.2

cation area to reserve the requested object allocation area.

`StackedMemory(SizeEstimator, Runnable)`

Signature

```
public  
StackedMemory(SizeEstimator scopeSize,  
               Runnable logic)
```

Create a guest `StackedMemory` with an object allocation area of the size estimated by the specified `SizeEstimator`, bound to the specified `Runnable`. The object allocation area is drawn from the same backing store as the parent scope's object allocation area. The parent scope must be a `StackedMemory`.

Parameters

`scopeSize` `SizeEstimator` indicating the size of the object allocation area
`logic` `Runnable` to be entered using `this` as its current memory area when `enter()`¹³⁹ is called.

Throws

`IllegalStateException` when the parent memory area is not a `StackedMemory`, or when the parent `StackedMemory` already has a child that is also a guest `StackedMemory`.

`IllegalArgumentException` when `scopeSize` is less than zero.

`java.lang.OutOfMemoryError` when there is insufficient memory available in the backing store of the parent `StackedMemory`'s object allocation area to reserve the requested object allocation area.

11.5.3.7.2 Methods

`resize(long)`

Signature

```
public  
void resize(long scopeSize)
```

¹³⁹Section 11.5.3.7.2

Change the size of the object allocation area for this scope. This method may be used to either grow or shrink the allocation area when there are no objects allocated in the scope and no **Schedulable** object has this area as its current allocation context. It may be used to shrink the allocation area down to the size of its current usage when the calling **Schedulable** object is the only object that has this area on its scope stack and there are no guest **StackedMemory** object allocation areas created after this area in the same backing store but not yet finalized.

Parameters

scopeSize The new allocation area size for this scope

Throws

IllegalStateException when the caller is not permitted to perform the requested adjustment or there are additional guest **StackedMemory** allocation areas after this one in the backing store.

javax.realtime.StaticOutOfMemoryError when the remaining backing store is insufficient for the requested adjustment.

getMaximumSize

Signature

```
public
long getMaximumSize()
```

Get the maximum size this memory area can attain. The value returned by this function is the maximum size that can currently be passed to **resize(long)**¹⁴⁰ without triggering an **OutOfMemoryException**.

Returns

The maximum size attainable.

enter

Signature

```
public
void enter()
```

Associate this memory area with the current **Schedulable** object for the duration of the **run()** method of the instance of **Runnable** given in this object's constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected.

¹⁴⁰Section 11.5.3.7.2

This method may only be called from the memory area in which this scope was created.

See Section `ScopedMemory.enter()`

Throws

`IllegalStateException` when the currently active memory area is a `StackedMemory` and is not the area in which this scope was created, or the current memory area is not a `StackedMemory` and this `StackedMemory` is not a root area.

`ThrowBoundaryError`

`IllegalThreadStateException`

`MemoryAccessError`

`enter(Runnable)`

Signature

```
public  
void enter(Runnable logic)
```

Associate this memory area with the current `Schedulable` object for the duration of the `run()` method of the given `Runnable`. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected.

This method may only be called from the memory area in which this scope was created.

See Section `ScopedMemory.enter(Runnable)`

Throws

`IllegalStateException` when the currently active memory area is a `StackedMemory` and is not the area in which this scope was created, or the current memory area is not a `StackedMemory` and this `StackedMemory` is not a root area.

`ThrowBoundaryError`

`IllegalThreadStateException`

`MemoryAccessError`

`joinAndEnter`

Signature

```
public  
void joinAndEnter()
```

Throws

IllegalStateException when the currently active memory area is a **StackedMemory** and is not the area in which this scope was created, or the current memory area is not a **StackedMemory** and this **StackedMemory** is not a root area.

IllegalThreadStateException
ThrowBoundaryError
javax.realtime.ScopedCycleException
MemoryAccessError

joinAndEnter(HighResolutionTime)

Signature

```
public  
void joinAndEnter(javax.realtime.HighResolutionTime<?> time)  
throws InterruptedException
```

Throws

IllegalStateException when the currently active memory area is a **StackedMemory** and is not the area in which this scope was created, or the current memory area is not a **StackedMemory** and this **StackedMemory** is not a root area.

InterruptedException
IllegalThreadStateException
javax.realtime.ThrowBoundaryError
javax.realtime.ScopedCycleException
javax.realtime.MemoryAccessError

joinAndEnter(Runnable)

Signature

```
public  
void joinAndEnter(Runnable logic)
```

throws `InterruptedException`

Throws

`IllegalStateException` when the currently active memory area is a `StackedMemory` and is not the area in which this scope was created, or the current memory area is not a `StackedMemory` and this `StackedMemory` is not a root area.

`InterruptedException`

`IllegalThreadStateException`

`javax.realtime.ThrowBoundaryError`

`javax.realtime.ScopedCycleException`

`javax.realtime.MemoryAccessError`

`joinAndEnter(Runnable, HighResolutionTime)`

Signature

```
public
void joinAndEnter(Runnable logic,
                  javax.realtime.HighResolutionTime<?> time)

throws InterruptedException
```

Throws

`IllegalStateException` when the currently active memory area is a `StackedMemory` and is not the area in which this scope was created, or the current memory area is not a `StackedMemory` and this `StackedMemory` is not a root area.

`InterruptedException`

`IllegalThreadStateException`

`javax.realtime.ThrowBoundaryError`

`javax.realtime.ScopedCycleException`

`javax.realtime.MemoryAccessError`

11.6 The Rationale

11.6.1 The Scoped Memory Model

Languages that employ automatic reclamation of blocks of memory allocated in what is conventionally called the heap by program logic also typically use an algorithm called a garbage collector. Garbage collection algorithms and implementations vary in the amount of non-determinacy they add to the execution of program logic. Rather than require a garbage collector, and require it to meet realtime constraints that would necessarily be a compromise, this specification constructs alternative systems for “safe” management of memory. The scoped and immortal memory areas allow program logic to allocate objects in a Java-like style, ignore the reclamation of those objects, and not incur the latency of the implemented garbage collection algorithm.

The term *scope stack* might mislead a reader to infer that it contains only scoped memory areas. This is incorrect. Although the scope stack may contain scoped memory references, it may also contain heap and immortal memory areas. Also, although the scope stack’s behavior is specified as a stack, an implementation is free to use any data structure that preserves the stack semantics.

This specification does not specifically address the lifetime of objects allocated in immortal memory areas. If they were reclaimed while they were still referenced, the referential integrity of the JVM would be compromised which is not permissible. Recovering immortal objects only at the termination of the application, or never recovering them under any circumstances is consistent with this specification.

If a scoped memory area is used by both heap and non-heap SOs, there could be cases where a finalizer executed in non-heap context could attempt to use a heap reference left by a heap-using SO. The code in the finalizer would throw a memory access error. If that exception is not caught in the finalizer, it will be handled by the implementation so finalization will continue undisturbed, but the problem in finalizer that caused the illegal memory access could be hard to locate. So, catch clauses in finalizers for objects allocated in scoped memory are even more useful than they are for normal finalizers.

Support for scoped non-default initial memory areas (SNDIMAs) for schedulables has repercussions. These repercussions include:

1. The SNDIMA’s parent is set when the SO is constructed, but its reference count is not incremented until the realtime thread is started or the async event handler becomes fireable. This lets a scope with a zero reference count have a parent. This may cause unexpected scoped cycle exceptions. The most surprising are from the `joinAndEnter` family of methods.
2. Finalization of a scoped memory (when its reference count goes to zero) can cause finalization of SNDIMAs of AEHs whose AEs are in the finalizing scope.

This can cause finalization of one scope to trigger finalization of numerous other scopes including scopes that are descendants of the scope whose finalization started the process.

3. Any action that makes an AEH non-fireable (directly disassociating it from all AEs, or indirectly disassociating it by finalizing the scopes containing those AEs) must block until all the resulting finalization completes.
4. Any action that makes an AEH fireable must block until any ongoing finalization of its SNDIMA completes.

These semantics are complicated (and so prone to bugs in use and in implementation), they may use significant CPU time at unexpected times, CPU time used for this finalization is not controlled by cost enforcement and it is hard to include in feasibility analysis. **Open issue:** This will not encourage the reader! **End of open issue**

Entering the scoped memory when the AEH is fired or the realtime thread starts has almost the same effect as using the scope as an initial memory area with much less complexity that is recommended practice. A future release may deprecate support for SNDIMAs. **Open issue:** *** **End of open issue**

Using heap or immortal memory as the non-default initial memory area of an SO is benign.

11.6.2 The Physical Memory Model

Embedded systems may have many different types of directly addressable memory available to them. Each type has its own characteristics [2] that determine whether it is

1. volatile – whether it maintains its state when the power is turned off;
2. writable – whether it can be written at all, written once or written many times and whether writing is under program control,
3. synchronous or asynchronous – whether the memory is synchronized with the system bus,
4. erasable at the byte level – if the memory can be overwritten whether this is done at the byte level or whether whole sectors of the memory need to be erased,
5. fast to access – both for reading and writing.

Examples include the following [2]:

1. *Dynamic Random Access Memory* (DRAM) and *Static Random Access Memory* (SRAM) – these are volatile memory types that are usually writable at the byte level. There are no limits on the number of times the memory contents can be written. From the embedded systems designer's view point, the main differences between the two are their access times and their costs per byte. SRAM has faster access times and is more expensive. Both DRAM

and SRAM are example of asynchronous memory, SDRAM and SSRAM are their synchronized counterparts. Another important difference is that DRAM requires periodic refresh operations, which may interfere with execution time determinism.

2. Read-Only Memory (for example, *Erasable Programmable Read-Only Memory* (EPROM)) – these are nonvolatile memory types that once initialized with data can not be overwritten by the program (without recourse to some external effect, usually ultraviolet light as in EPROM). They are fast to access and cost less per byte than DRAM.
3. Hybrid Memory (for example, *Electrically Erasable Programmable Read-Only Memory* (EEPROM), and Flash) – these have some properties of both random access and read-only memory.
 - (a) EEPROM – this is nonvolatile memory that is writable at the byte level. However, there are typically limits on how many time the same location can be overwritten. EEPROMs are expensive to manufacture, fast to read but slow to write.
 - (b) FLASH memory – this is nonvolatile that is writable at the sector level. Like EEPROM there are limits on how many times the same location can be overwritten and they are fast to read but slow to write. Flash memory is cheaper to manufacture than EEPROM.

Some embedded systems may have multiple types of random-access memory, and multiple ways of accessing memory. For instance, there may be a small amount of very fast RAM on the processor chip, memory that is on the same board as the processor, memory that may be added and removed from the system dynamically, memory that is accessed across a bus, access to memory that is mediated by a cache, access where the cache is partially disabled so all stores are “write through”, memory that is demand paged, and other types of memory and memory-access attributes only limited by physics and the imagination of electrical engineers. Some of these memory types will have no impact on the programmer, others will.

Individual computers are often targeted at a particular application domain. This domain will often dictate the cost and performance requirements, and therefore, the memory type used. Some embedded systems are highly optimized and need to explore different options in memory to meet their performance requirements. Here are five example scenarios.

1. Ninety percent of performance-critical memory access is to a set of objects that could fit in a half the total memory.
2. The system enables the locking of a small amount of data in the cache, and a small number of pages in the translation lookaside buffer (TLB). A few very frequently accessed objects are to be locked in the cache and a larger number of objects that have jitter requirements can be TLB-locked to avoid TLB faults.

3. The boards accept added memory on daughter boards, but that memory is not accessible to DMA from the disk and network controllers and it cannot be used for video buffers. Better performance is obtained if we ensure that all data that might interact with disk, network, or video is not stored on the daughter board.
4. Improved video performance can be obtained by using an array as a video buffer. This will only be effective if a physically contiguous, non-pageable, DMA-accessible block of RAM is used for the buffer and all stores forced to write through the cache. Of course, such an approach is dependent on the way the JVM lays out arrays in memory, and it breaks the JVM abstraction by depending on that layout.
5. The system has banks of SRAM and saves power by automatically putting them to “sleep” whenever they stay unused for 100 ms or so. To exploit this, the objects used by each phase of our program can be collected in a separate bank of this special memory.

To be clear, few embedded systems are this aggressive in their hardware optimization. The majority of embedded systems have only ROM, RAM, and maybe flash memory. Configuration-controlled memory attributes (such as page locking, and TLB behavior) are more common.

As well as having different types of memory, many computers map input and output devices so that their registers can be accessed as if they were resident within the computer memory (see Section 12.3.1). Hence, some parts of the processor’s address space map to real memory and other parts map to device registers. Logically, even a device’s memory can be considered part of the memory hierarchy, even where the device’s interface is accessed through special assembly instructions. Multiprocessor systems add a further dimension to the problem of memory access. Memory may be local to a CPU, tightly shared between CPUs, or remotely accessible from the CPU (but with a delay).

Traditionally, Java programmers are not concerned with these low-level issues; they program at a higher level of abstraction and assume the JVM makes judicious use of the underlying resources provided by the execution platform¹⁴¹. Embedded systems programmers cannot afford this luxury. Consequently, any Java environment that wishes to facilitate the programming of embedded systems must enable the programmer to exercise more control over memory.

11.6.2.1 Problems with the RTSJ 1.0.2 Physical Memory Framework

The RTSJ 1.0.2 supported three ways to allocate objects that can be placed in particular types of memory:

¹⁴¹This is reflected by the OS support provided. For example, most POSIX systems only offer programs a choice of demand paged or page-locked memory.

1. `ImmortalPhysicalMemory` allocates immortal objects in memory with specified characteristics.
2. `LTPhysicalMemory` allocates scoped memory objects in a memory with specified characteristics using a linear time memory allocation algorithm.
3. `VTPhysicalMemory` allocates scoped memory objects in memory with specified characteristics using an algorithm that may be worse than linear time but could offer extra services (such as extensibility).

The only difference between the physical memory classes and the corresponding non-physical classes is that the ordinary memory classes give access to normal system RAM and the physical memory classes offer access to particular types of memory.

The RTSJ 1.0.2 supports access to physical memory via a memory manager and one or more memory filters. The goal of the memory manager is to provide a single interface with which the programmer can interact in order to access memory with a particular characteristic. A memory filter enables access to a particular type of physical memory. Memory filters may be dynamically added and removed from the system, and there can only be a single filter for each memory type. The memory manager is unaware of the physical addresses of each type of memory. This is encapsulated by the filters. The filters also know the virtual memory characteristics that have been allocated to their memory type. For example, whether the memory is readable or writable.

In theory, any developer can create a new physical memory filter and register it with the PMM. However, the programming of filters is difficult for the following reasons.

1. Physical memory type filters include a memory allocation function that must respond to allocation requests with whether a requested range of physical memory is free and if it is not, the physical address of the next free physical memory of the requested type. This is complex because requests for compound types of physical memory must find a free segment that satisfies all attributes of the compound type.
2. The Java runtime must continue to behave correctly under the Java memory model when it is using physical memory. This is not a problem when a memory type behaves like the system's normal RAM with respect to the properties addressed by the memory model, or is more restricted than normal RAM (as, for instance, write-through cache is more restricted than copy-back cache). If a new memory type does not obey the memory model using the same instruction sequences as normal RAM, the memory filter must cooperate with the interpreter, the JIT, and any ahead-of-time compilation to modify those instruction sequences when accessing the new type of memory. That task is difficult for someone who can easily modify the Java runtime and nearly impossible for anyone else.

Hence, the utility of the physical memory filter framework at Version 1.0.2 is questionable, and hence is replaced in 2.0 with an easier to use framework.

11.6.2.2 The RTSJ 2.0 Physical Memory Framework

The main problem with the 1.0.2 framework is that it places too greater a burden on the JVM implementer. Even for embedded systems, the JVM implementer requires the VM to be portable between systems within the same processor family. It, therefore, cannot have detailed knowledge of the underlying memory architecture. It is only concerned with the standard RAM provided to it by the host operating system.

The design of 2.0 model is based on two constraints.

1. Java objects can only be allocated in a memory area if the physical backing store supports the Java Memory Model without the JVM having to perform any operation addition to those that it performs when accessing as the main RAM for the host machine. No extra compiler or JVM interactions shall be required. Hence memory types (such as EEPROM), which potentially require special hardware instructions to perform write operations, cannot be used as the backing store for physical memory areas. Similarly, non-volatile memory can be used any objects store therein may contain references to objects in volatile memory. Although these memory types are prohibited from being used as backing stores, they contain objects of primitive Java types and be accessed via the RTSJ Raw Memory facilities (see Section 12.3.1).
2. Any API must delegates detailed knowledge of the memory architecture to the programmer of the specific embedded system to be implemented. There is less requirement for portability here, as embedded systems are usually optimized for their host environment. The model assumes that the programmer is aware of the memory map, either through some native operating system interface¹⁴² or from some property file read at program initialization time.

When accessing physical memory, there are two main considerations:

1. the characteristics of the required physical memory, and
2. how that memory is to be mapped into the virtual memory of the application.

2.0 requires the program to identify (and inform the RTSJ's physical memory manager of) the physical memory characteristics and the range of physical addresses those characteristic apply to. For example, that there is SRAM between physical address range 0x100000000 and 0xA0000000.

¹⁴²For example, the *Advanced Configuration and Power Interface* (ACPI) specification is an open standard for device configuration and power management by the operating system. The ACPI defines platform-independent interfaces for hardware discovery, configuration, power management and monitoring. See <http://www.acpi.info/>

The physical memory manager supports a range of options for mapping physical memory into the virtual memory of the application. Examples of such options are whether the range is to be permanently resident in memory (the default is that it may be subject to paging/swapping), and whether data is written to the cache and the main memory simultaneously (i.e., a write through cache).

Given the required physical and virtual memory characteristics, the programmer requests that the PMM creates a memory filter for accessing this memory. This filter can then be used with new constructors on the physical memory classes. For example,

```
1 public ImmortalPhysicalMemory(PhysicalMemoryFilter filter, long size)
```

Use of this constructor enables the programmer to specify the allocation of the backing store in a particular type of memory with a particular virtual memory characteristic. The filter is used to locate an area in physical memory with the required physical memory characteristics and to direct its mapping into the virtual address space. Other constructors allow multiple filters to be passed.

Hence, once the filters have been created, physical memory areas can be created and objects can be allocated within those memory areas using the usual RTSJ mechanisms for changing the allocation context of the **new** operator.

11.6.2.3 An example

Consider an example of a system that has a SRAM physical memory module configured at a physical base address of 0x10000000 and of length 0x20000000. Another module (base address of 0xA0000000 and of length 0x10000000) also supports SRAM, but this module has been configured so that it saves power by sleeping when not in use. The following subsections illustrate how the embedded programmer informs the PMM about the structure during the program's initialization phase, and how the memory may be subsequently used after this. The example assumes that the PMM supports the virtual memory characteristics defined above.

Program Initialization

For simplicity, the example requires that the address of the memory modules are known, rather than being read from a property file. The program needs to have a class that implements the `PhysicalMemoryCharacteristic`. In this simple example, this is empty.

```
1 public class MyMemoryType implements PhysicalMemoryCharacteristic {}
```

The initialization method must now create instances of the `PhysicalMemoryRegion` class to represent the physical memory module memory modules to represent

```

1 PhysicalMemoryRegion staticRam =
2   new PhysicalMemoryRegion(0x100000000L, 0x100000000L);
3 PhysicalMemoryRegion staticSleepableRam =
4   new PhysicalMemoryRegion(0xA00000000L, 0x100000000L);

```

It then creates names for the characteristics that the program wants to associate with each memory module.

```

1 PhysicalMemoryCharacteristic STATIC_RAM = new MyMemoryType();
2 PhysicalMemoryCharacteristic AUTO_SLEEPABLE = new MyMemoryType();

```

It then informs the PMM of the appropriate associations:

```

1 PhysicalMemoryFactory.associate(STATIC_RAM, staticRam);
2 PhysicalMemoryFactory.associate(STATIC_RAM, staticSleepableRam);
3 PhysicalMemoryFactory.associate(AUTO_SLEEPABLE, staticSleepableRam);

```

Once this is done, the program can now create a filter with the required properties. In this case it is for some SRAM that must be auto sleepable.

```

1 PhysicalMemoryCharacteristic [] PMC =
2   new PhysicalMemoryCharacteristic[2];
3 PMC[0] = STATIC_RAM;
4 PMC[1] = AUTO_SLEEPABLE;
5
6 PhysicalMemorySelector selector =
7   new PhysicalMemorySelector(PMC, null, DISABLED, FIXED);

```

If the program had just asked for SRAM then either of the memory modules could satisfy the request.

The initialization is now complete, and the programmer can use the memory for storing objects, as shown below.

Using Physical Memory

Once the programmer has configured the JVM so that it is aware of the physical memory modules, and the programmer names for characteristics of those memory modules, using the physical memory is straight forward. Here is an example.

```

1   ImmortalMemory IM = factory.createImmortalMemory(selector, 0x1000);
2   IM.enter(new Runnable()

```

```
3  {  
4    public void run()  
5    {  
6        // The code executing here is running with its allocation  
7        // context set to a physical immortal memory area that is  
8        // mapped to RAM which is auto sleepable.  
9        // Any objects created will be placed in that  
10       // part of physical memory.  
11    }  
12  });
```

It is the appropriate constructor of the physical memory classes that now interfaces with the PMM. The physical memory manager keeps track of previously allocated memory and is able to determine if memory is available with the appropriate characteristics. Of course, the PMM has no knowledge of what these names mean; it is merely providing a look-up service.

Chapter 12

Devices and Triggering

12.1 Overview

Interacting with the external environment in a timely manner is an important requirement for realtime, embedded systems. From an embedded systems' perspective, all interactions with the physical world are performed by input and output devices. Hence, the problem is one of controlling and monitoring of devices. This is an area insufficiently addressed by other Java standards. A conventional Java Virtual Machine is not designed to support device access and interrupt handling. Programs that need this functionality must resort to code written in another language and called via the Java Native Interface (JNI). This specification addresses the problem by providing APIs for interrupt handling and direct memory access without resorting to JNI.

In contrast to earlier versions of this specification, 2.0 has extended the goals of the device interfaces to be type safe and user extensible, so that the user can defined new devices without changing the underlying virtual machine.

There are at least four execution (runtime) environments for the RTSJ:

1. on a realtime operating system where the Java application runs in user mode;
2. on a realtime operating system where the Java application runs in a context with a user space device driver;
3. as a “kernel module” incorporated into a realtime kernel where both kernel and application run in supervisor mode; and
4. as part of an embedded device where the Java application runs stand-alone on a hardware machine.

In execution environment 1, interaction with the embedded environment is usually via operating system calls using Java's connection-oriented APIs. The Java program will typically have no direct access to the I/O devices. Although some limited access to physical memory may be provided, it is unlikely that interrupts

can be directly handled. However, asynchronous interaction with the environment is still possible, for example, via POSIX signals.

In execution environments 2, 3, and 4, the Java program may be able to directly access devices and handle interrupts.

A device can be anything from a simple set of registers wired to sensors and actuators to a full processor performing some fixed task. The interface to a device is usually through a set of device registers. Depending on the I/O architecture of the processor, the programmer can either access these registers via predetermined memory location (called *memory mapped I/O*) or via special assembler instructions (called *port-mapped I/O*).

A computer system with processing devices can be considered to be a collection of parallel threads. The device ‘thread’ can communicate and synchronize with the tasks executing inside the main processor either by having the main processor poll registers of the device or via a signal from the device. This signal is usually referred to as an interrupt. All high-level models of device programming must provide [3]

1. facilities for representing, addressing and manipulating device registers; and
2. a suitable representation of interrupts (if interrupts are to be handled).

Version 1.0 of the RTSJ went some way towards supporting this model through the notion of *happenings* and the *raw memory* access facilities. Unfortunately, happenings were under defined and the mechanisms for physical and raw memory were overly complex with no clear delineation of the separations of concerns between application developers and JVM implementers.

2.0 has significantly enhanced the support for happenings, and has provided a clearer separation between physical and raw memory. The interfaces for `Happening`, `Timer`, and `POSIXSignal` are now unified under `ActiveEvent`. This means that both `Happening` and `POSIXSignal`, like `Timer` are now subclasses of `AsyncEventHandler`. As described in Chapter 8, `ActiveEvent` provides a common light-weight means of notifying that its event has occurred. Unlike `fire()`, where dispatching of the associated handlers is done in context of the caller, an `ActiveEvent` separates this notification that the event occurred, its triggering, from the dispatching by providing its own execution context for the dispatching. As with `Timer`, each class has its own `ActiveEventDispatcher`: `HappeningDispatcher`, `POSIXSignalDispatcher`, and `TimeDispatcher`. Finally, support for POSIX realtime signals is provided by `POSIXRealtimeSignal` with its associated dispatcher.

12.2 Definitions

A *happening* is an event that takes place outside the Java runtime environment. The triggers for happenings depend on the external environment, but happenings might include signals and interrupts.

12.3 Semantics

The classes in this Chapter are part of the Memory Module introduced in Section 3.2.3 and are only required in implementations that include that module. There are several aspects of the API for supporting devices. Raw Memory provides the means of accessing the I/O register of a device. Direct Memory Access (DMA) support provides a means of transferring data using a DMA controller. Active events and dispatchers support releasing event handlers based on external events. Interrupt service routines and application-defined clocks are for linking external events to the active events.

12.3.1 Raw Memory

Raw Memory provides means of accessing particular physical memory addresses as variables of Java's primitive data types, and thereby provides an application with direct access to physical memory, for example, for memory-mapped I/O.

Java objects or references therefore *cannot* be stored in raw memory. The following specifies the RTSJ's facilities for raw memory access.

- Each area of memory supporting raw memory access is identified by a subclass of `RawMemoryRegion`.
 - The raw memory region `RawMemoryFactory.MEMORY_MAPPED_REGION` facilitates access to memory locations that are outside the main memory used by the JVM. It is used to access input and output device registers when such registers are memory mapped.
 - The raw memory region `RawMemoryFactory.IO_PORT_MAPPED_REGION` facilitates access to locations that are outside the main memory used by the JVM. It is used to access input and output device registers when such registers are port-based and can only be accessed by special hardware instructions.
 - The application developer can define and register additional regions to support things like emulated access to devices or access to a bus over a bus controller.
- Access to raw memory is controlled by implementation-defined objects, called *accessor objects*. These implement specification-defined interfaces (e.g., `RawByte`, `RawShort`, `RawInt`, etc.) and are created by implementation-defined factory objects. Each factory implements the `RawMemoryRegionFactory` interface, and is identified by its `RawMemoryRegion`.
- The `RawMemoryFactory` class defines the applications programmers interface to the raw memory facilities.
- The `RawMemoryRegionFactory` interface defines the interface that all factories must support for creating accessor objects.

Figure 12.1: Raw Memory Interface

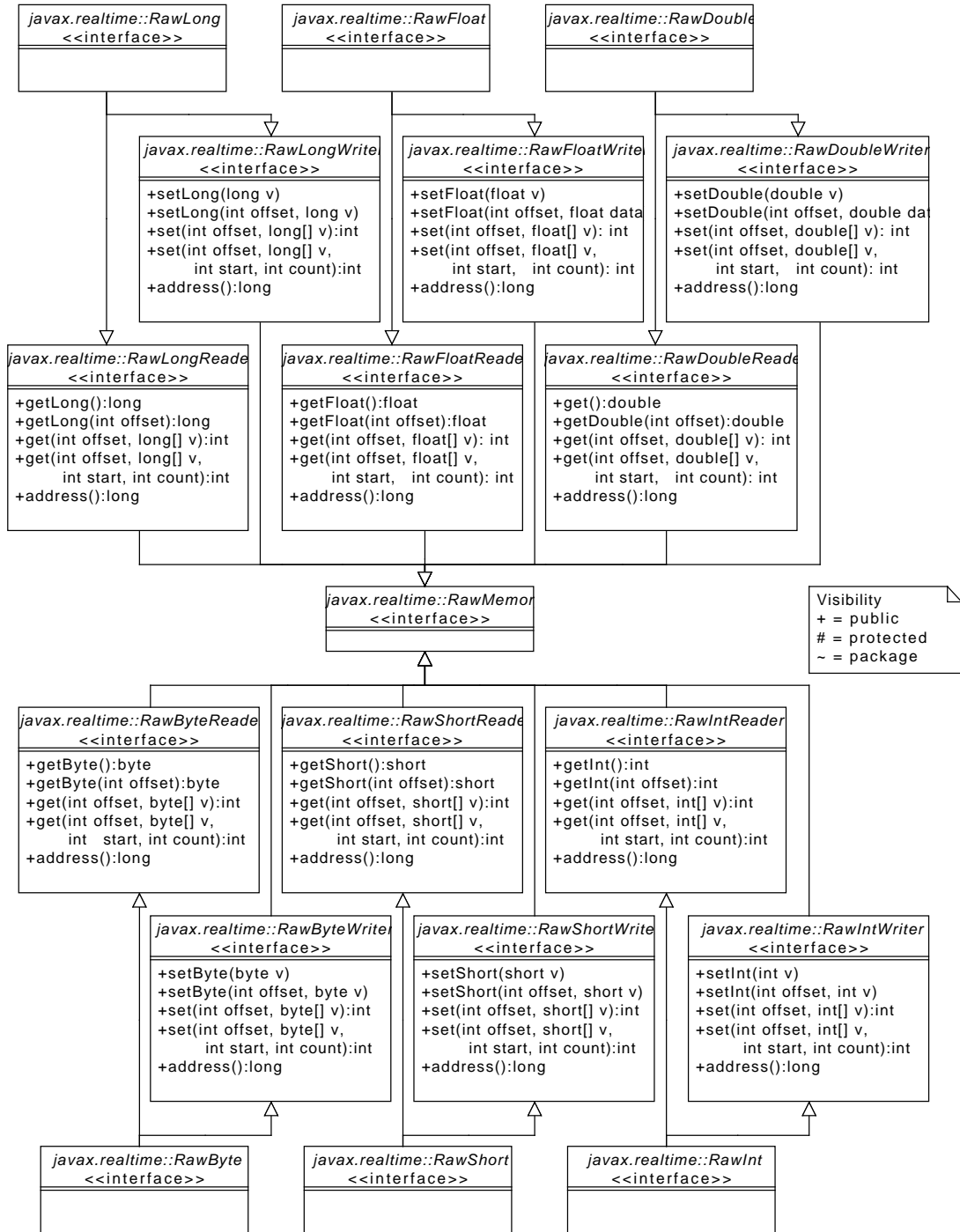
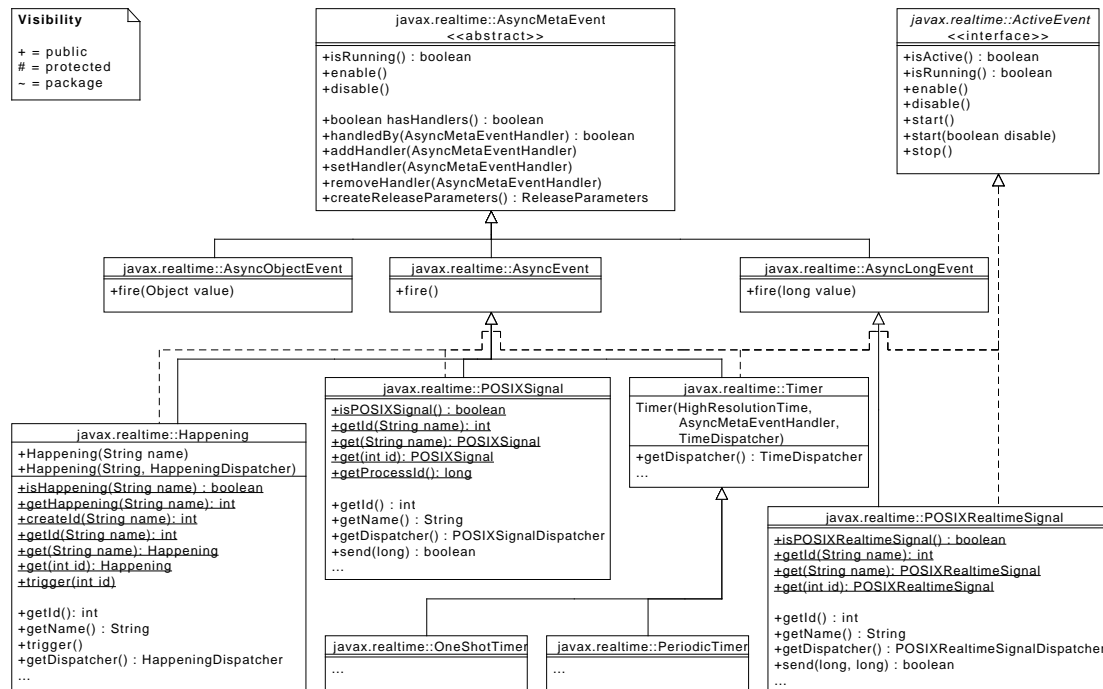


Figure 12.2: Event Classes



12.3.1.1 Raw Memory Region

Raw memory is designed to support arbitrary I/O address spaces. The simplest is through the processor address space and is accessible via standard memory access instructions, such as `load` and `store`. This provides access to memory mapped I/O devices, but there are other address spaces as well. Each of these address spaces is referred to as a *Raw Memory Region*.

There are two raw memory regions that can be supported generically. Memory mapped I/O is one. The other is port mapped I/O. The most common instance is the I/O space provided by Intel x86 compatible processors through their `in` and `out` instructions. The memory mapped I/O raw memory region must be supported by all implementations, but the port mapped I/O raw memory region must only be supported on processors that support it.

All other raw memory regions are optional and may be provided by a system integrator or an application developer. The API provides an interface, `RawMemoryRegionFactory`, that can be implemented to provide a means of creating accessor objects for that region. These additional regions can be anything from an I/O space provided by a memory mapped device, using memory mapped I/O to implement it,

to a purely synthetic I/O space to emulated hardware that has not yet been built.

Each raw memory region is identified by its raw memory region object. These “types” are defined by instances of `RawMemoryRegion`: `RawMemoryFactory.MEMORY_MAPPED_REGION` for memory mapped devices and `RawMemoryFactory.IO_PORT_MAPPED_REGION` for port mapped devices for processors that have instructions for reading and writing an I/O bus directly. The instances are used to get accessors of a region instead of using a `RawMemoryRegionFactory` directly.

12.3.1.2 Raw Memory Factory

In order to support a variety of device address spaces efficiently, raw memory objects are created using the factory methods provided by `RawMemoryFactory`. This factory provides static methods to get accessors for a region via a region’s type. Regions created during runtime can be provided by registering their factory with the main raw memory factory, so the application code only needs to have a reference to the object identifying the required region. For instance, one could create an I2C raw memory region by implementing a factory for it using a memory mapped I2C controller.

12.3.1.3 Stride

Since the word size of devices do not always match the word size of the memory or I/O bus, the interface provides for the notion of stride. Stride defines the distance between elements in a raw memory area. Normally elements of a memory area are mapped sequentially, without any space between the elements. This is a stride of one. A stride of two, means that every other element in physical memory is mapped into the raw memory area.

For example, it is often easier to map a 16 bit device into a 32 bit system by mapping the 16 bit registers at 32 bit intervals. This enables 16 bit accesses to the device to be atomic on 32 bit addressed systems, even when the bus always does 32 bit transfers. One can create a `RawShort` area with a stride of two. Then the area can be accessed as if the registers were contiguous.

Since stride is designed to support mapping devices that have a smaller word size than the host machine, the implementation is allowed to assume that the padding between values is “do not care” data, and can be overwritten arbitrarily.

12.3.2 Direct Memory Access Support

Many embedded systems provide a means of moving data without direct involvement of the main processor. This is typically programmed with a special device called a DMA controller. DMA controllers are treated specially since they are central to bulk

transfer in device drivers. The data to be transferred is not in device registers, but in normal RAM. Java already provides an API for managing this kind of memory in `java.nio`. The DMA API defined here provides a seamless means of integrating those features into a device driver for DMA.

There are various architectures for DMA controllers, each requiring its own programming paradigm, so only common low level support is provided by this specification. Raw memory can be used to program the DMA controller, but there needs to be a means of representing bulk data. The `java.nio.ByteBuffer` provides just such a representation. The only difference is that the restrictions on the memory behind byte buffer objects is a bit different than for other `java.nio` mechanisms.

These differences are covered with a special byte buffer factory: `RawBufferFactory`. An instance of this factory can produce direct byte buffers within a given memory range. This range can be chosen by the programmer to be within the range of a given DMA controller. The factory also provides methods for getting the start address of a buffer's memory and checking if a buffer's memory is within a given range. These addresses should be compatible with DMA controllers in the system, though for controllers with a smaller address space than the processor, the DMA address may have fixed offset from the processor physical address. The `RawBufferFactory` class also provides static methods for ensuring that Java-generated changes to DMA-mapped memory buffers are visible to native code, and vice-versa.

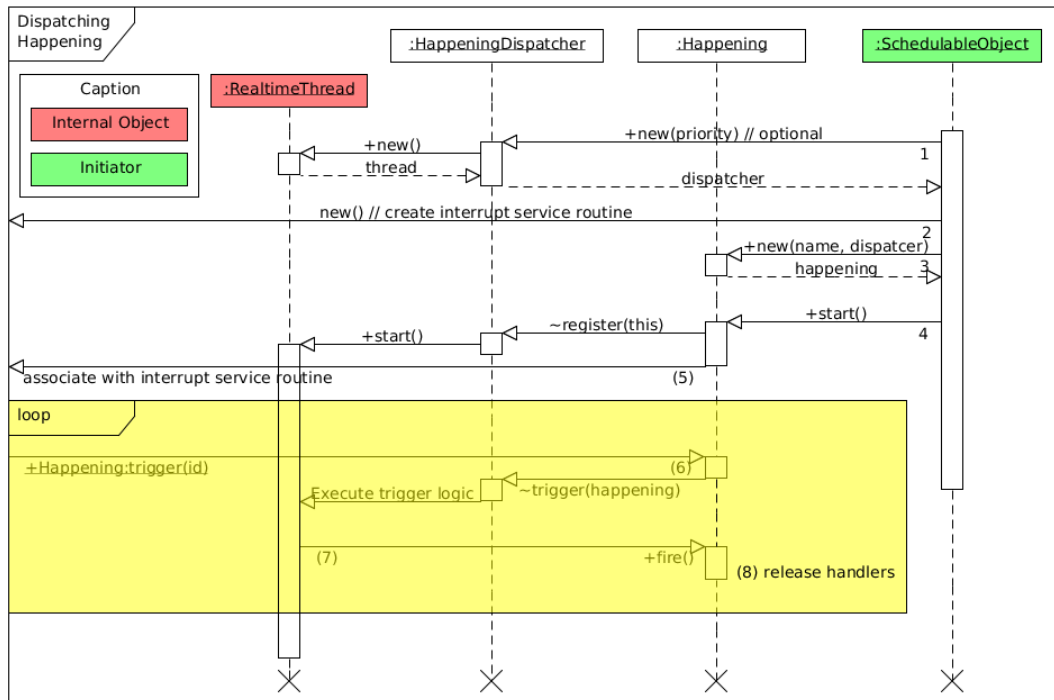
12.3.3 External Triggering

It is not enough to be able to read from and write to devices; many applications, need a means of being interrupted when an event happens. This specification provides a two-level interrupt mechanism. For predefined interfaces, such as POSIX signals, the first level handler is provided by the virtual machine and asynchronous events provide the second level event handling. For external events and additional clocks, where the programmer needs to be able to define new instances and provide for their triggering, additional classes are provided to manage both the first level, as well as the second level handling. In all cases, the user can control the priority and affinity of the dispatching between the first level and second level handling.

12.3.3.1 Happenings

Whereas, in previous versions of this specification, happenings were represented as a `String`, as of 2.0 they have become an object in their own right. This makes it easier to properly type methods that use them and for the user to define new happening for an application without the need to change the JVM. Furthermore, indirection is minimized by making the new `Happening` class a subclass of `AsyncEvent`.

Figure 12.3: Happening State Transition Diagram



Since a **Happening** needs to be triggerable from an external event, such as an interrupt, the **Happening** class also implements **ActiveEvent**. As with other active events, **Happening** has its own dispatcher class: **HappeningDispatcher**. There is a default happening dispatcher that is used when none is provided at creation time, otherwise, the programmer can provide one to change the priority and affinity of dispatching.

Normally, happenings are triggered either from an **InterruptServiceRoutine** or from JNI code. For the later, the interface provides a means of linking a happening by name. This enables native code to get a handle for triggering a happening without have a direct reference. The given name must follow the Java naming conventions. A happening name defined outside of this specification should not begin with `java.` or `javax..`

Figure 12.3 illustrates the sequence of actions necessary for defining and using a **Happening**. When using an application defined dispatcher, it must be created first (1). When using an **InterruptServiceRoutine** to trigger the happening, it may be created before (2) or after the happening is create. After creating the happening (3), the happening must be started to be registered with it dispatcher

12.3.4 Interrupt Service Routines

In Java-based systems, JNI is typically used to transfer control between the assembler/C *interrupt service routine* (ISR) and the program. 2.0 of the RTSJ supports the possibility of the ISR containing Java code. This is clearly an area where it is difficult to maintain the portability goal of Java. Furthermore, not all RTSJ deployments can support `InterruptServiceRoutine`. A JVM that runs in user space does not generally have access to interrupts.

The JVM must either be standalone, running in a kernel module, or running in a special I/O partition on a partitioning OS where interrupts are passed through using some virtualization technique. Hence, JVM support for ISR is not required for RTSJ compliance.

Interrupt handling is necessarily machine dependent. However, the RTSJ provides an abstract model that can be implemented on top of all architectures.

The following semantic model shall be supported by the RTSJ:

- An *occurrence* of an interrupt consists of its *generation* and *delivery*.
- Generation of the interrupt is the mechanism in the underlying hardware or system that makes the interrupt available to the Java program.
- Delivery is the action that invokes an interrupt service routine (ISR) in response to the occurrence of the interrupt. This may be performed by the JVM or application native code linked with the JVM, or directly by the hardware interrupt mechanism.
- Between generation and delivery, the interrupt is *pending*.
- Some or all interrupt occurrences may be inhibited. While an interrupt occurrence is inhibited, all occurrences of that interrupt shall be prevented from being delivered. Whether such occurrences remain pending or are lost is implementation defined, but it is expected that the implementation shall make a best effort to avoid losing pending interrupts.
- Certain implementation-defined interrupts are *reserved*. Reserved interrupts are either interrupts for which application-defined ISRs are not supported, or those that already have ISRs by some other implementation-defined means. For example, a clock interrupt, which is used for internal time keeping by the JVM, is a reserved interrupt.
- An application-defined ISR can be registered with one or more non-reserved interrupts. Registering an ISR for an interrupt shall implicitly deregister any already registered ISR for that interrupt. Any daisy-chaining of interrupt handlers shall be performed explicitly by the application interrupt handlers.
- While an ISR is registered to an interrupt, the `handle` method shall be called *once* for each delivery of that interrupt. For locking out further interrupts during interrupt handling, the `handle` method must be synchronized with a priority high enough to lock out the requisite interrupts. This synchronized

uses priority ceiling emulation to inhibit the corresponding interrupt (and all lower priority interrupts). The default allocation context of the `handle` method is the memory area passed during construction.

Any exception propagated from the `handle` method shall be caught by the JVM and ignored.

- Code running in the context of an ISR may only attempt to acquire a lock that has priority ceiling emulation as its monitor control policy. The behavior is undefined, when an ISR attempt to acquire a lock that has a monitor control policy other than priority ceiling emulation. **Open issue:** jjh: Do we want to support a mechanism of static checking here? **End of open issue**

The model assumes that

- the processor has a (logical) interrupt controller that monitors a number of *interrupt lines*;
- the interrupt controller may associate each interrupt line with a particular interrupt priority;
- associated with the interrupt lines is a (logical) interrupt vector that contains the addresses of the ISRs;
- the processor has instructions that allow interrupts from a particular line to be disabled/masked irrespective of whether (or the type of) device attached;
- disabling interrupts from a specific line may disables the interrupts from lines of lower priority;
- a device can be connected to an arbitrary interrupt line;
- when an interrupt is signalled on an interrupt line by a device, the processor uses the identity of the interrupt line to index into the interrupt vector and jumps to the address of the ISR; the hardware automatically disables further interrupts (either of the same priority and lower or, possibly, all interrupts);
- on return from the ISR, interrupts are automatically re-enabled.

For each of the interrupt, the RTSJ has an associated hardware priority that can be used to set the ceiling of an ISR object. The RTSJ virtual machine may use this to disable the interrupts from the associated interrupt line and lower priority interrupts, when it is executing a synchronized method of the interrupt-handling object. On a multicore system, the situation is more complex, since there may be other cores available to handle other interrupts, even at lower priorities, and some other locking mechanism may be necessary as well.

Though synchronization is not required in general, it is required to enforce visibility of changes made to any variables shared between some normal `Schedulable` and a `handle` method. For the `handle` method, this may be done automatically by the hardware interrupt handling mechanism or it may require added support from the realtime Java virtual machine. However, for clarity of the model, RTSJ recommends that the `handle` method should be defined as synchronized.

Support for interrupt handling is encapsulated in the `InterruptServiceRoutine` abstract class that has two main methods. The first is the final `register` method that will register an instance of the class with the system so that the appropriate interrupt vector can be initialized. The second is the abstract `handle` method that provides the code to be executed in response to the interrupt occurring. An individual real-time JVM may place restrictions of the code that can be written in this method. The process is illustrated in Figure 12.4, and is described below.

1. The ISR is created by some application real-time thread.
2. The created ISR is registered with the JVM, the interrupt id is passed as a parameter.
3. As part of the registration process, some internal interface is used to set up the code that will set the underlying interrupt vectors to some C/assembly code that will provide the necessary linkage to allow the callback to the Java handler.
4. When the interrupt occurs, the handler is called.

In order to integrate further the interrupt handling with the Java application, the `handle` method may trigger a happening or fire an event.

Typically an implementation of the RTSJ that supports first-level interrupt handling will document the following items:

1. For each interrupt, its identifying integer value, the priority at which the interrupt occurs and whether it can be inhibited or not, and the effects of registering ISRs to non-inhabitable interrupts (if this is permitted).
2. Which run-time stack the `handle` method uses when it executes.
3. Any implementation- or hardware-specific activity that happens before the `handle` method is invoked (e.g., reading device registers, acknowledging devices).
4. The state (inhibited/uninhibited) of the nonreserved interrupts when the program starts; if some interrupts are uninhibited, what the mechanism is that a program can use to protect itself before it can register the corresponding ISR.
5. The treatment of interrupt occurrences that are generated while the interrupt is inhibited; i.e., whether one or more occurrences are held for later delivery, or all are lost.
6. Whether predefined or implementation-defined exceptions are raised as a result of the occurrence of any interrupt (for example, a hardware trap resulting from a segmentation error), and the mapping between the interrupt and the predefined exceptions.
7. On a multiprocessor, the rules governing the delivery of an interrupt occurrence to a particular processor. For example, whether execution of the `handle` method may spin if the lock of the associated object is held by another processor.

12.4 Package javax.realtime.device

12.4.1 Interfaces

12.4.1.1 RawByte

Interfaces

[RawByteReader](#)

[RawByteWriter](#)

A marker for an object that can be used to access to a single byte. Read and write access to that byte is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

12.4.1.2 RawByteReader

Interfaces

[RawMemory](#)

A marker for a byte accessor object encapsulating the protocol for reading bytes from raw memory. A byte accessor can always access at least one byte. Each byte is transferred in a single atomic operation. Groups of bytes may be transferred together; however, this is not required.

Objects of this type are created with the method [RawMemoryFactory.createRawByteReader](#)¹ and [RawMemoryFactory.createRawByte](#)². Each object references a range of elements in the [RawMemoryRegion](#)³ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.2.1 Methods

¹Section [12.4.2.5.3](#)

²Section [12.4.2.5.3](#)

³Section [12.4.2.6](#)

getBytes

Signature

```
public  
byte getBytes()
```

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getBytes(int)

Signature

```
public  
byte getBytes(int offset)  
throws OffsetOutOfBoundsException
```

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of byte in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, byte)

Signature

```
public  
int get(int offset,  
        byte[] values)
```

throws `OffsetOutOfBoundsException`,
`NullPointerException`

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the bytes in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first byte in the memory region to transfere

values the array to received the bytes

Throws

`OffsetOutOfBoundsException` when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

`NullPointerException` when **values** is null.

Returns

the number of elements copied to **values**

get(int, byte, int, int)

Signature

```
public
int get(int offset,
        byte[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
ArrayIndexOutOfBoundsException,
NullPointerException
```

Fill **values** with data from the memory region, where **offset** is first byte in the memory region and **start** is the first index in **values**. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

offset of the first byte in the memory region to transfere

values the array to received the bytes

start the first index in array to fill

count the maximum number of bytes to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.

`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of values.

`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of bytes actually transfered.

12.4.1.3 RawByteWriter*Interfaces***RawMemory**

A marker for a byte accessor object encapsulating the protocol for writing bytes from raw memory. A byte accessor can always access at least one byte. Each byte is transfered in a single atomic operation. Groups of bytes may be transfered together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawByteWriter`⁴ and `RawMemoryFactory.createRawByte`⁵. Each object references a range of elements in the `RawMemoryRegion`⁶ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.3.1 Methods**setByte(byte)***Signature*

⁴Section [12.4.2.5.3](#)

⁵Section [12.4.2.5.3](#)

⁶Section [12.4.2.6](#)


```
public
void setByte(byte value)
```

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setByte(int, byte)

Signature

```
public
void setByte(int offset,
              byte value)
throws OffsetOutOfBoundsException
```

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + **offset** * *size of Byte*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of byte in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, byte)

Signature

```
public
int set(int offset,
        byte[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**.

Only the bytes in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of byte in the memory region.

values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, byte, int, int)

Signature

```
public
int set(int offset,
        byte[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Copy **values** to the memory region, where **offset** is first byte in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

offset of the first byte in the memory region to set

values the array from which to retrieve the bytes

start the first index in array to fill

count the maximum number of bytes to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.

ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.

`NullPointerException` when `values` is null.

Returns

the number of bytes actually transferred.

12.4.1.4 RawDouble

Interfaces

[RawDoubleReader](#)

[RawDoubleWriter](#)

A marker for an object that can be used to access to a single double. Read and write access to that double is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

12.4.1.5 RawDoubleReader

Interfaces

[RawMemory](#)

A marker for a double accessor object encapsulating the protocol for reading doubles from raw memory. A double accessor can always access at least one double. Each double is transferred in a single atomic operation. Groups of doubles may be transferred together; however, this is not required.

Objects of this type are created with the method [RawMemoryFactory.createRawDoubleReader](#)⁷ and [RawMemoryFactory.createRawDouble](#)⁸. Each object references a range of elements in the [RawMemoryRegion](#)⁹ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.5.1 Methods

⁷Section [12.4.2.5.3](#)

⁸Section [12.4.2.5.3](#)

⁹Section [12.4.2.6](#)

getDouble

Signature

```
public  
double getDouble()
```

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getDouble(int)

Signature

```
public  
double getDouble(int offset)  
throws OffsetOutOfBoundsException
```

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of double in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, double)

Signature

```
public  
int get(int offset,  
        double[] values)
```

throws `OffsetOutOfBoundsException`,
`NullPointerException`

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the doubles in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first double in the memory region to transfere

values the array to received the doubles

Throws

`OffsetOutOfBoundsException` when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

`NullPointerException` when **values** is null.

Returns

the number of elements copied to **values**

get(int, double, int, int)

Signature

```
public
int get(int offset,
        double[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
ArrayIndexOutOfBoundsException,
NullPointerException
```

Fill **values** with data from the memory region, where **offset** is first double in the memory region and **start** is the first index in **values**. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

offset of the first double in the memory region to transfere

values the array to received the doubles

start the first index in array to fill

count the maximum number of doubles to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.

`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of values.

`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of doubles actually transfered.

12.4.1.6 RawDoubleWriter*Interfaces***RawMemory**

A marker for a double accessor object encapsulating the protocol for writing doubles from raw memory. A double accessor can always access at least one double. Each double is transfered in a single atomic operation. Groups of doubles may be transfered together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawDoubleWriter`¹⁰ and `RawMemoryFactory.createRawDouble`¹¹. Each object references a range of elements in the `RawMemoryRegion`¹² starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.6.1 Methods**setDouble(double)***Signature*

¹⁰Section [12.4.2.5.3](#)

¹¹Section [12.4.2.5.3](#)

¹²Section [12.4.2.6](#)

```
public
void setDouble(double value)
```

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setDouble(int, double)

Signature

```
public
void setDouble(int offset,
               double value)
throws OffsetOutOfBoundsException
```

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + **offset** * *size of Double*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of double in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, double)

Signature

```
public
int set(int offset,
        double[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**.

Only the doubles in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of double in the memory region.
values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.
NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, double, int, int)

Signature

```
public
int set(int offset,
        double[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Copy **values** to the memory region, where **offset** is first double in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

offset of the first double in the memory region to set
values the array from which to retrieve the doubles
start the first index in array to fill
count the maximum number of doubles to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.
ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.

`NullPointerException` when `values` is null.

Returns

the number of doubles actually transferred.

12.4.1.7 RawFloat

Interfaces

[RawFloatReader](#)

[RawFloatWriter](#)

A marker for an object that can be used to access to a single float. Read and write access to that float is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

12.4.1.8 RawFloatReader

Interfaces

[RawMemory](#)

A marker for a float accessor object encapsulating the protocol for reading floats from raw memory. A float accessor can always access at least one float. Each float is transferred in a single atomic operation. Groups of floats may be transferred together; however, this is not required.

Objects of this type are created with the method [RawMemoryFactory.createRawFloatReader](#)¹³ and [RawMemoryFactory.createRawFloat](#)¹⁴. Each object references a range of elements in the [RawMemoryRegion](#)¹⁵ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.8.1 Methods

¹³Section [12.4.2.5.3](#)

¹⁴Section [12.4.2.5.3](#)

¹⁵Section [12.4.2.6](#)

getFloat

Signature

```
public  
float getFloat()
```

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getFloat(int)

Signature

```
public  
float getFloat(int offset)  
throws OffsetOutOfBoundsException
```

Get the value of the n^{th} element referenced by this instance, where *n* is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of float in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, float)

Signature

```
public  
int get(int offset,  
        float[] values)
```

throws `OffsetOutOfBoundsException`,
`NullPointerException`

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the floats in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first float in the memory region to transfere

values the array to received the floats

Throws

`OffsetOutOfBoundsException` when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

`NullPointerException` when **values** is null.

Returns

the number of elements copied to **values**

get(int, float, int, int)

Signature

```
public
int get(int offset,
        float[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
ArrayIndexOutOfBoundsException,
NullPointerException
```

Fill **values** with data from the memory region, where **offset** is first float in the memory region and **start** is the first index in **values**. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

offset of the first float in the memory region to transfere

values the array to received the floats

start the first index in array to fill

count the maximum number of floats to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.

`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of values.

`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of floats actually transfered.

12.4.1.9 RawFloatWriter*Interfaces***RawMemory**

A marker for a float accessor object encapsulating the protocol for writing floats from raw memory. A float accessor can always access at least one float. Each float is transfered in a single atomic operation. Groups of floats may be transfered together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawFloatWriter`¹⁶ and `RawMemoryFactory.createRawFloat`¹⁷. Each object references a range of elements in the `RawMemoryRegion`¹⁸ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.9.1 Methods**setFloat(float)***Signature*

¹⁶Section [12.4.2.5.3](#)

¹⁷Section [12.4.2.5.3](#)

¹⁸Section [12.4.2.6](#)

```
public
void setFloat(float value)
```

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setFloat(int, float)

Signature

```
public
void setFloat(int offset,
              float value)
throws OffsetOutOfBoundsException
```

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address + offset * size of Float*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of float in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, float)

Signature

```
public
int set(int offset,
        float[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**.

Only the floats in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of float in the memory region.

values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, float, int, int)

Signature

```
public
int set(int offset,
        float[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Copy **values** to the memory region, where **offset** is first float in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

offset of the first float in the memory region to set

values the array from which to retrieve the floats

start the first index in array to fill

count the maximum number of floats to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.

ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.

`NullPointerException` when `values` is null.

Returns

the number of floats actually transfered.

12.4.1.10 RawInt

Interfaces

[RawIntReader](#)

[RawIntWriter](#)

A marker for an object that can be used to access to a single int. Read and write access to that int is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

12.4.1.11 RawIntReader

Interfaces

[RawMemory](#)

A marker for a int accessor object encapsulating the protocol for reading ints from raw memory. A int accessor can always access at least one int. Each int is transfered in a single atomic operation. Groups of ints may be transfered together; however, this is not required.

Objects of this type are created with the method [RawMemoryFactory.createRawIntReader](#)¹⁹ and [RawMemoryFactory.createRawInt](#)²⁰. Each object references a range of elements in the [RawMemoryRegion](#)²¹ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.11.1 Methods

¹⁹Section [12.4.2.5.3](#)

²⁰Section [12.4.2.5.3](#)

²¹Section [12.4.2.6](#)

getInt

Signature

```
public  
int getInt()
```

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getInt(int)

Signature

```
public  
int getInt(int offset)  
throws OffsetOutOfBoundsException
```

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of int in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, int)

Signature

```
public  
int get(int offset,  
        int[] values)
```


throws `OffsetOutOfBoundsException`,
`NullPointerException`

Fill the `values` starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's `stride`. Only the ints in the intersection of the start and end of `values` and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

`offset` of the first int in the memory region to transfere

`values` the array to received the ints

Throws

`OffsetOutOfBoundsException` when `offset` is negative or greater than or equal to the number of elements in the raw memory region.

`NullPointerException` when `values` is null.

Returns

the number of elements copied to `values`

`get(int, int, int, int)`

Signature

```
public
int get(int offset,
        int[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
ArrayIndexOutOfBoundsException,
NullPointerException
```

Fill `values` with data from the memory region, where `offset` is first int in the memory region and `start` is the first index in `values`. The number of bytes transferred is the minimum of `count`, the *size* of the memory region minus `offset`, and length of `values` minus `start`. When an exception is thrown, no data is transferred.

Parameters

`offset` of the first int in the memory region to transfere

`values` the array to received the ints

`start` the first index in array to fill

`count` the maximum number of ints to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.

`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of values.

`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of ints actually transfered.

12.4.1.12 RawIntWriter*Interfaces***RawMemory**

A marker for a int accessor object encapsulating the protocol for writing ints from raw memory. A int accessor can always access at least one int. Each int is transfered in a single atomic operation. Groups of ints may be transfered together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawIntWriter`²² and `RawMemoryFactory.createRawInt`²³. Each object references a range of elements in the `RawMemoryRegion`²⁴ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.12.1 Methods**setInt(int)***Signature*

²²Section [12.4.2.5.3](#)

²³Section [12.4.2.5.3](#)

²⁴Section [12.4.2.6](#)

```
public
void setInt(int value)
```

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setInt(int, int)

Signature

```
public
void setInt(int offset,
            int value)
throws OffsetOutOfBoundsException
```

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + **offset** * *size of Int*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of int in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, int)

Signature

```
public
int set(int offset,
        int[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**.

Only the ints in the intersection of **values** and the end of the memory region are transfered. When an exception is thrown, no data is transfered.

Parameters

offset of int in the memory region.

values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, int, int, int)

Signature

```
public
int set(int offset,
        int[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Copy **values** to the memory region, where **offset** is first int in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transfered is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transfered.

Parameters

offset of the first int in the memory region to set

values the array from which to retrieve the ints

start the first index in array to fill

count the maximum number of ints to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.

ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.

`NullPointerException` when `values` is null.

Returns

the number of ints actually transferred.

12.4.1.13 RawLong

Interfaces

[RawLongReader](#)

[RawLongWriter](#)

A marker for an object that can be used to access to a single long. Read and write access to that long is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

12.4.1.14 RawLongReader

Interfaces

[RawMemory](#)

A marker for a long accessor object encapsulating the protocol for reading longs from raw memory. A long accessor can always access at least one long. Each long is transferred in a single atomic operation. Groups of longs may be transferred together; however, this is not required.

Objects of this type are created with the method [RawMemoryFactory.createRawLongReader](#)²⁵ and [RawMemoryFactory.createRawLong](#)²⁶. Each object references a range of elements in the [RawMemoryRegion](#)²⁷ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.14.1 Methods

²⁵Section [12.4.2.5.3](#)

²⁶Section [12.4.2.5.3](#)

²⁷Section [12.4.2.6](#)

getLong

Signature

```
public  
long getLong()
```

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getLong(int)

Signature

```
public  
long getLong(int offset)  
throws OffsetOutOfBoundsException
```

Get the value of the n^{th} element referenced by this instance, where *n* is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of long in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, long)

Signature

```
public  
int get(int offset,  
        long[] values)
```

throws `OffsetOutOfBoundsException`,
`NullPointerException`

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the longs in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first long in the memory region to transfere

values the array to received the longs

Throws

`OffsetOutOfBoundsException` when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

`NullPointerException` when **values** is null.

Returns

the number of elements copied to **values**

get(int, long, int, int)

Signature

```
public
int get(int offset,
        long[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
ArrayIndexOutOfBoundsException,
NullPointerException
```

Fill **values** with data from the memory region, where **offset** is first long in the memory region and **start** is the first index in **values**. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

offset of the first long in the memory region to transfere

values the array to received the longs

start the first index in array to fill

count the maximum number of longs to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.

`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of values.

`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of longs actually transfered.

12.4.1.15 RawLongWriter*Interfaces***RawMemory**

A marker for a long accessor object encapsulating the protocol for writing longs from raw memory. A long accessor can always access at least one long. Each long is transfered in a single atomic operation. Groups of longs may be transfered together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawLongWriter`²⁸ and `RawMemoryFactory.createRawLong`²⁹. Each object references a range of elements in the `RawMemoryRegion`³⁰ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.15.1 Methods**setLong(long)***Signature*

²⁸Section [12.4.2.5.3](#)

²⁹Section [12.4.2.5.3](#)

³⁰Section [12.4.2.6](#)


```
public
void setLong(long value)
```

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setLong(int, long)

Signature

```
public
void setLong(int offset,
              long value)
throws OffsetOutOfBoundsException
```

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + **offset** * *size of Long*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of long in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, long)

Signature

```
public
int set(int offset,
        long[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**.

Only the longs in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of long in the memory region.

values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, long, int, int)

Signature

```
public
int set(int offset,
        long[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Copy **values** to the memory region, where **offset** is first long in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

offset of the first long in the memory region to set

values the array from which to retrieve the longs

start the first index in array to fill

count the maximum number of longs to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.

ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.

`NullPointerException` when `values` is null.

Returns

the number of longs actually transferred.

12.4.1.16 RawMemory

A marker for all raw memory accessor objects.

12.4.1.16.1 Methods

getAddress

Signature

```
public  
long getAddress()
```

Get the base physical address of this object.

Returns

the first physical address this raw memory object can access.

getSize

Signature

```
public  
int getSize()
```

Get the number of bytes that this object spans.

Returns

the size of this raw memory

getStride

Signature

```
public  
int getStride()
```

Get the distance between elements in multiples of element size.

Returns

the span between elements of this raw memory

12.4.1.17 RawMemoryRegionFactory

A class to give an application the ability to provide support for a [RawMemoryRegion](#)³¹ that is not already provided by the standard. An instance of this class can be registered with a [RawMemoryFactory](#)³² and provides the object that that factory should return for a given [RawMemoryRegion](#). It is responsible for checking all requests and throwing the proper exception when a request is invalid or the requester is not authorized to make the request.

12.4.1.17.1 Methods

getRegion

Signature

```
public
    javax.realtime.device.RawMemoryRegion getRegion()
```

Determine for what region this factory creates raw memory objects.

Returns

the region of this factory.

getName

Signature

```
public
    java.lang.String getName()
```

Determine the name of the region for which this factory creates raw memory objects.

Returns

³¹Section [12.4.2.6](#)

³²Section [12.4.2.5](#)

the name of the region of this factory.

createRawByte(long, int, int)

Signature

```
public
javax.realtime.device.RawByte createRawByte(long base,
                                             int count,
                                             int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        UnsupportedRawMemoryRegionException,
        MemoryTypeConflictException
```

Create an instance of a class that implements [RawByte](#)³³ and accesses memory of [getRegion](#)³⁴ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawByte * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

³³Section [12.4.1.1](#)

³⁴Section [12.4.1.17.1](#)

an object that implements [RawByte](#)³⁵ and supports access to the specified range in the memory region.

createRawByteReader(long, int, int)

Signature

```
public
javax.realtime.device.RawByteReader createRawByteReader(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements [RawByteReader](#)³⁶ and accesses memory of [getRegion](#)³⁷ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawByteReader * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

³⁵Section [12.4.1.1](#)

³⁶Section [12.4.1.2](#)

³⁷Section [12.4.1.17.1](#)

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawByteReader`³⁸ and supports access to the specified range in the memory region.

`createRawByteWriter(long, int, int)`

Signature

```
public
javax.realtime.device.RawByteWriter createRawByteWriter(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements `RawByteWriter`³⁹ and accesses memory of `getRegion`⁴⁰ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawByteWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

³⁸Section 12.4.1.2

³⁹Section 12.4.1.3

⁴⁰Section 12.4.1.17.1

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawByteWriter**⁴¹ and supports access to the specified range in the memory region.

createRawShort(long, int, int)

Signature

```
public
javax.realtime.device.RawShort createRawShort(long base,
                                              int count,
                                              int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements **RawShort**⁴² and accesses memory of **getRegion**⁴³ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawShort * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

⁴¹Section 12.4.1.3

⁴²Section 12.4.1.18

⁴³Section 12.4.1.17.1

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawShort`⁴⁴ and supports access to the specified range in the memory region.

`createRawShortReader(long, int, int)`

Signature

```
public
javax.realtime.device.RawShortReader createRawShortReader(long base,
                                                            int count,
                                                            int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements `RawShortReader`⁴⁵ and accesses memory of `getRegion`⁴⁶ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawShortReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.

⁴⁴Section 12.4.1.18

⁴⁵Section 12.4.1.19

⁴⁶Section 12.4.1.17.1

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawShortReader**⁴⁷ and supports access to the specified range in the memory region.

createRawShortWriter(long, int, int)

Signature

```
public
javax.realtime.device.RawShortWriter createRawShortWriter(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements **RawShortWriter**⁴⁸ and accesses memory of **getRegion**⁴⁹ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawShortWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

⁴⁷Section 12.4.1.19

⁴⁸Section 12.4.1.20

⁴⁹Section 12.4.1.17.1

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawShortWriter**⁵⁰ and supports access to the specified range in the memory region.

createRawInt(long, int, int)

Signature

```
public
javax.realtime.device.RawInt createRawInt(long base,
                                           int count,
                                           int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements **RawInt**⁵¹ and accesses memory of **getRegion**⁵² in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawInt * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

⁵⁰Section 12.4.1.20

⁵¹Section 12.4.1.10

⁵²Section 12.4.1.17.1

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawInt`⁵³ and supports access to the specified range in the memory region.

createRawIntReader(long, int, int)*Signature*

```
public
javax.realtime.device.RawIntReader createRawIntReader(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        UnsupportedRawMemoryRegionException,
        MemoryTypeConflictException
```

Create an instance of a class that implements `RawIntReader`⁵⁴ and accesses memory of `getRegion`⁵⁵ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawIntReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

⁵³Section 12.4.1.10

⁵⁴Section 12.4.1.11

⁵⁵Section 12.4.1.17.1

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawIntReader](#)⁵⁶ and supports access to the specified range in the memory region.

createRawIntWriter(long, int, int)

Signature

```
public
javax.realtime.device.RawIntWriter createRawIntWriter(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements [RawIntWriter](#)⁵⁷ and accesses memory of [getRegion](#)⁵⁸ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawIntWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

⁵⁶Section [12.4.1.11](#)

⁵⁷Section [12.4.1.12](#)

⁵⁸Section [12.4.1.17.1](#)

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawIntWriter](#)⁵⁹ and supports access to the specified range in the memory region.

createRawLong(long, int, int)

Signature

```
public
javax.realtime.device.RawLong createRawLong(long base,
                                             int count,
                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements [RawLong](#)⁶⁰ and accesses memory of [getRegion](#)⁶¹ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawLong * count**. The object is allocated in the current memory area of the calling thread.

Parameters

⁵⁹Section [12.4.1.12](#)

⁶⁰Section [12.4.1.13](#)

⁶¹Section [12.4.1.17.1](#)

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when **base** is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawLong`⁶² and supports access to the specified range in the memory region.

createRawLongReader(long, int, int)

Signature

```
public
javax.realtime.device.RawLongReader createRawLongReader(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements `RawLongReader`⁶³ and accesses memory of `getRegion`⁶⁴ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawLongReader* * **count**. The object is allocated in the current memory area of the

⁶²Section 12.4.1.13

⁶³Section 12.4.1.14

⁶⁴Section 12.4.1.17.1

calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawLongReader](#)⁶⁵ and supports access to the specified range in the memory region.

createRawLongWriter(long, int, int)

Signature

```
public
javax.realtime.device.RawLongWriter createRawLongWriter(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements [RawLongWriter](#)⁶⁶ and accesses memory of [getRegion](#)⁶⁷ in the address range described by **base**, **stride**, and **count**.

⁶⁵Section [12.4.1.14](#)

⁶⁶Section [12.4.1.15](#)

⁶⁷Section [12.4.1.17.1](#)

The actual extent of the memory addressed by the object is `stride * size of RawLongWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

- base** The starting physical address accessible through the returned instance.
- count** The number of memory elements accessible through the returned instance.
- stride** The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

- `IllegalArgumentException` when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.
- `SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.
- `OffsetOutOfBoundsException` when **base** is invalid.
- `SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.
- `MemoryTypeConflictException` when **base** does not point to memory that matches the type served by this factory.

Returns

- an object that implements `RawLongWriter`⁶⁸ and supports access to the specified range in the memory region.

createRawFloat(long, int, int)

Signature

```
public
javax.realtime.device.RawFloat createRawFloat(long base,
                                              int count,
                                              int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Create an instance of a class that implements `RawFloat`⁶⁹ and accesses memory

⁶⁸Section 12.4.1.15

⁶⁹Section 12.4.1.7

of `getRegion`⁷⁰ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawFloat * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawFloat`⁷¹ and supports access to the specified range in the memory region.

createRawFloatReader(long, int, int)

Signature

```
public
javax.realtime.device.RawFloatReader createRawFloatReader(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

⁷⁰Section 12.4.1.17.1

⁷¹Section 12.4.1.7

Create an instance of a class that implements [RawFloatReader](#)⁷² and accesses memory of [getRegion](#)⁷³ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawFloatReader* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when **base** is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawFloatReader](#)⁷⁴ and supports access to the specified range in the memory region.

createRawFloatWriter(long, int, int)

Signature

```
public
javax.realtime.device.RawFloatWriter createRawFloatWriter(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
```

⁷²Section [12.4.1.8](#)

⁷³Section [12.4.1.17.1](#)

⁷⁴Section [12.4.1.8](#)

MemoryTypeConflictException

Create an instance of a class that implements [RawFloatWriter](#)⁷⁵ and accesses memory of [getRegion](#)⁷⁶ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawFloatWriter* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

[IllegalArgumentException](#) when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

[SecurityException](#) when the caller does not have permissions to access the given memory region or the specified range of addresses.

[OffsetOutOfBoundsException](#) when **base** is invalid.

[SizeOutOfBoundsException](#) when the memory addressed by the object would extend into an invalid range of memory.

[MemoryTypeConflictException](#) when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawFloatWriter](#)⁷⁷ and supports access to the specified range in the memory region.

createRawDouble(long, int, int)

Signature

```
public
javax.realtime.device.RawDouble createRawDouble(long base,
                                                int count,
                                                int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
```

⁷⁵Section [12.4.1.9](#)

⁷⁶Section [12.4.1.17.1](#)

⁷⁷Section [12.4.1.9](#)

UnsupportedRawMemoryRegionException,
MemoryTypeConflictException

Create an instance of a class that implements [RawDouble](#)⁷⁸ and accesses memory of [getRegion](#)⁷⁹ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawDouble* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

[IllegalArgumentException](#) when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

[SecurityException](#) when the caller does not have permissions to access the given memory region or the specified range of addresses.

[OffsetOutOfBoundsException](#) when **base** is invalid.

[SizeOutOfBoundsException](#) when the memory addressed by the object would extend into an invalid range of memory.

[MemoryTypeConflictException](#) when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawDouble](#)⁸⁰ and supports access to the specified range in the memory region.

createRawDoubleReader(long, int, int)

Signature

```
public
javax.realtime.device.RawDoubleReader createRawDoubleReader(long base,
                                                             int count,
                                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
```

⁷⁸Section [12.4.1.4](#)

⁷⁹Section [12.4.1.17.1](#)

⁸⁰Section [12.4.1.4](#)

SizeOutOfBoundsException,
 UnsupportedRawMemoryRegionException,
 MemoryTypeConflictException

Create an instance of a class that implements [RawDoubleReader](#)⁸¹ and accesses memory of [getRegion](#)⁸² in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawDoubleReader* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawDoubleReader](#)⁸³ and supports access to the specified range in the memory region.

createRawDoubleWriter(long, int, int)

Signature

```
public
javax.realtime.device.RawDoubleWriter createRawDoubleWriter(long base,
                                                             int count,
                                                             int stride)
```

⁸¹Section [12.4.1.5](#)

⁸²Section [12.4.1.17.1](#)

⁸³Section [12.4.1.5](#)

throws `SecurityException`,
`OffsetOutOfBoundsException`,
`SizeOutOfBoundsException`,
`UnsupportedRawMemoryRegionException`,
`MemoryTypeConflictException`

Create an instance of a class that implements `RawDoubleWriter`⁸⁴ and accesses memory of `getRegion`⁸⁵ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawDoubleWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawDoubleWriter`⁸⁶ and supports access to the specified range in the memory region.

12.4.1.18 RawShort

Interfaces

`RawShortReader`

⁸⁴Section 12.4.1.6

⁸⁵Section 12.4.1.17.1

⁸⁶Section 12.4.1.6

RawShortWriter

A marker for an object that can be used to access to a single short. Read and write access to that short is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

12.4.1.19 RawShortReader

Interfaces

RawMemory

A marker for a short accessor object encapsulating the protocol for reading shorts from raw memory. A short accessor can always access at least one short. Each short is transferred in a single atomic operation. Groups of shorts may be transferred together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawShortReader`⁸⁷ and `RawMemoryFactory.createRawShort`⁸⁸. Each object references a range of elements in the `RawMemoryRegion`⁸⁹ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.19.1 Methods

getShort

Signature

```
public
short getShort()
```

⁸⁷Section 12.4.2.5.3

⁸⁸Section 12.4.2.5.3

⁸⁹Section 12.4.2.6

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getShort(int)

Signature

```
public
short getShort(int offset)
throws OffsetOutOfBoundsException
```

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of short in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, short)

Signature

```
public
int get(int offset,
        short[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the shorts in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first short in the memory region to transfere

values the array to received the shorts

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

get(int, short, int, int)

Signature

```
public
int get(int offset,
        short[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Fill **values** with data from the memory region, where **offset** is first short in the memory region and **start** is the first index in **values**. The number of bytes transfered is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transfered.

Parameters

offset of the first short in the memory region to transfere

values the array to received the shorts

start the first index in array to fill

count the maximum number of shorts to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.

ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.

NullPointerException when **values** is null or **count** is negative.

Returns

the number of shorts actually transfered.

12.4.1.20 RawShortWriter

Interfaces

RawMemory

A marker for a short accessor object encapsulating the protocol for writing shorts from raw memory. A short accessor can always access at least one short. Each short is transferred in a single atomic operation. Groups of shorts may be transferred together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawShortWriter`⁹⁰ and `RawMemoryFactory.createRawShort`⁹¹. Each object references a range of elements in the `RawMemoryRegion`⁹² starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

12.4.1.20.1 Methods

setShort(short)

Signature

```
public
void setShort(short value)
```

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

⁹⁰Section [12.4.2.5.3](#)

⁹¹Section [12.4.2.5.3](#)

⁹²Section [12.4.2.6](#)

setShort(int, short)

Signature

```
public
void setShort(int offset,
              short value)
throws OffsetOutOfBoundsException
```

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address + offset * size of Short*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of short in the memory region.
value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, short)

Signature

```
public
int set(int offset,
        short[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**. Only the shorts in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of short in the memory region.
values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.
NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, short, int, int)*Signature*

```
public
int set(int offset,
        short[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Copy **values** to the memory region, where **offset** is first short in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transfered is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transfered.

Parameters

offset of the first short in the memory region to set

values the array from which to retrieve the shorts

start the first index in array to fill

count the maximum number of shorts to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.

ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.

NullPointerException when **values** is null.

Returns

the number of shorts actually transfered.

12.4.2 Classes

12.4.2.1 Happening

Inheritance

```

java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncEvent
      javax.realtime.device.Happening

```

Interfaces

```

  ActiveEvent

```

This class provides second level handling for external events such as interrupts. A happening can be triggered by an **InterruptServiceRoutine**⁹³ or from native code. Application defined **Happenings** can be identified by an application provided name or a system provided **id**, both of which must be unique. A system **Happening** has a name provide by the system which is a string beginning with @.

12.4.2.1.1 Constructors**Happening(String, HappeningDispatcher)***Signature*

```

public
Happening(String name,
           HappeningDispatcher dispatcher)
throws IllegalArgumentException

```

Create a Happening with the given name.

Parameters

name of the happening.
dispatcher to use when being triggered.

Throws

IllegalArgumentException when name does not match the pattern full identifier naming convention, i.e., package plus name. An implementation may throw this exception for all names starting with java. and javax.

Happening(String)*Signature*

⁹³Section 12.4.2.3

```
public  
Happening(String name)  
throws IllegalArgumentException
```

Create a `Happening` with the given name.

Parameters

name of the happening.

Throws

`IllegalArgumentException` when name does not match the pattern full type naming convention, i.e., package plus name. An implementation may throw this exception for all names starting with `java.` and `javax.`

12.4.2.1.2 Methods

getHappening(String)

Signature

```
public static  
javax.realtime.device.Happening getHappening(String name)
```

Find an active happening by its name. A `Happening` is only registered when it is active. When it is stopped, it is automatically deregistered.

Parameters

name of the happening to get.

Returns

a reference to the happening with name **name**, or `null` if no happening is found.

isHappening(String)

Signature

```
public static  
boolean isHappening(String name)
```

Is there an active happening with name **name**?

Parameters

name A string that might name an active happening.

Returns

True only when there is a registered happening with the name **name**.

createId(String)

Signature

```
public static  
int createId(String name)  
throws IllegalStateException
```

Sets up a mapping between a **name** and a system dependent ID. This can be called either in the constructor of an instance of [InterruptServiceRoutine](#)⁹⁴ or in native code that sets up an interrupt service routine to link it with a **Happening**. Once created, it cannot be removed.

This must take no more than linear time in the number of ID (**n**) registered, but should be $O(\log_2(n))$.

Parameters

name is a happening name string.

Throws

IllegalStateException when **name** is already registered.

Returns

an ID assigned by the system

getId(String)

Signature

```
public static  
int getId(String name)
```

Return the ID of **name**, when one exists or -1, when **name** is not registered.

This must take no more than linear time in the number of ID (**n**) registered, but should be $O(\log_2(n))$.

Parameters

name is a happening name string.

Returns

The id, or -1 when no happening is found with that name.

get(int)

Signature

⁹⁴Section [12.4.2.3](#)


```
public static  
    javax.realtime.device.Happening get(int id)
```

Get the external event corresponding to a given `id`.

Parameters

`id` of a registered signal

Returns

the signal corresponding to `id`.

get(String)

Signature

```
public static  
    javax.realtime.device.Happening get(String name)
```

Get the external event corresponding to a given `name`.

Parameters

`name` of a registered signal

Returns

the signal corresponding to `name`.

trigger(int)

Signature

```
public static  
    boolean trigger(int id)
```

Causes the event dispatcher corresponding to `happeningId` to be scheduled for execution. The implementation should be simple enough so that it can be done in the context of an `InterruptServiceRoutine.handle`⁹⁵ method.

`trigger()` and any native code analog to it interact with other `ActiveEvent`⁹⁶ code effectively as if `trigger()` signals a POSIX counting semaphore that the happening is waiting on.

The implementation is encouraged to create (and document) a native code analog to this method that can be used without a Java context.

This method must execute in constant time.

Parameters

⁹⁵Section 12.4.2.3.2

⁹⁶Section 8.4.1.1

`id` identifies which happening to trigger.

Returns

true if a happening with id `happeningId` was found, false otherwise.

getId

Signature

```
public final  
int getId()
```

Get the number of this happening.

Returns

the happening number or -1, when not registered.

getName

Signature

```
public  
java.lang.String getName()
```

Get the name of this happening.

Returns

the name of this happening.

start

Signature

```
public  
void start()  
throws IllegalStateException
```

Start this **Happening**, i.e., change to the active and enabled state. Once a happening is started the first time, when it is in a scoped memory it increments the scope count of that scope; otherwise, it becomes a member of the root set. An active and enabled happening dispatches its handlers when fired.

[See Section stop\(\)](#)

Throws

IllegalStateException when this **Happening** has already been started or its **name** is already in use by another happening that has been started.

start(boolean)

Signature

```
public
void start(boolean disabled)
throws IllegalStateException
```

Start this **Happening**, but leave it in the disabled state. When fired before being enabled, it does not dispatch its handlers.

See [Section stop\(\)](#)

Parameters

`disabled` true for starting in a disabled state.

Throws

`IllegalStateException` when this **Happening** has already been started.

stop

Signature

```
public
boolean stop()
throws IllegalStateException
```

Stop this happening from responding to the `fire` and `trigger` methods.

Throws

`IllegalStateException` when this **Happening** is not active.

Returns

`true` when this is in the *enabled* state `false` otherwise.

isActive

Signature

```
public
boolean isActive()
```

Determine the activation state of this happening, i.e., it has been started.

Returns

`true` when active, `false` otherwise.

isRunning

Signature

```
public
boolean isRunning()
```

Determine whether or not this **Happening** is both active and enabled.

Returns

true when this **Happening** is both active and enabled, **false** otherwise.

trigger

Signature

```
public
void trigger()
```

Causes the event dispatcher associated with **this** to be scheduled for execution. The implementation should be simple enough so that it can be done in the context of an **InterruptServiceRoutine.handle**⁹⁷ method.

This method must execute in constant time.

getDispatcher

Signature

```
public
javax.realtime.device.HappeningDispatcher getDispatcher()
```

12.4.2.2 HappeningDispatcher

Inheritance

```
java.lang.Object
  javax.realtime.ActiveEventDispatcher
    javax.realtime.device.HappeningDispatcher
```

This class provides a means of dispatching a set of **Happening**⁹⁸. The **process()** method is called each time the signal is triggered.

⁹⁷Section 12.4.2.3.2

⁹⁸Section 12.4.2.1

12.4.2.2.1 Constructors

HappeningDispatcher(SchedulingParameters)

Signature

```
public  
HappeningDispatcher(SchedulingParameters schedule)
```

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`schedule` give the parameters for scheduling this dispatcher

12.4.2.2.2 Methods

register(Happening)

Signature

```
public synchronized  
void register(Happening happening)  
throws RegistrationException,  
        IllegalStateException,  
        IllegalArgumentException
```

Register a [Happening](#)⁹⁹ with this dispatcher.

Parameters

`happening` to register

Throws

`RegistrationException` when `happening` is already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `happening` is not stopped.

⁹⁹Section [12.4.2.1](#)

unregister(Happening)

Signature

```
public synchronized
void unregister(Happening happening)
throws DeregistrationException,
       IllegalStateException,
       IllegalArgumentException
```

Deregister a [Happening](#)¹⁰⁰ from this dispatcher.

Parameters

happening to unregister

Throws

DeregistrationException when happening is not already registered.

IllegalStateException when this object has been destroyed.

IllegalArgumentException when happening is not stopped.

destroy

Signature

```
public
void destroy()
throws IllegalStateException
```

Release all resources thereby making the dispatcher unusable.

Throws

IllegalStateException when called on a dispatcher that has one or more registered [Happening](#)¹⁰¹ objects.

12.4.2.3 InterruptServiceRoutine

Inheritance

```
java.lang.Object
  javax.realtime.device.InterruptServiceRoutine
```

Interfaces

```
RealtimeExecutionContext
```

¹⁰⁰Section [12.4.2.1](#)

¹⁰¹Section [12.4.2.1](#)

A class for defining a first level interrupt handler. The implementation must override the `handle`¹⁰² method to provide the code to be run when an interrupt occurs. This class must always be present in the Device module, but may do nothing in a context that does not provide direct access to interrupts, e.g., in user space on an operating system that does not support user space device drivers.

12.4.2.3.1 Constructors

InterruptServiceRoutine(MemoryArea)

Signature

```
public
InterruptServiceRoutine(MemoryArea area)
throws NullPointerException,
    IllegalArgumentException
```

Create an interrupt service routine with a particular memory area.

Parameters

`area` the allocation context in which the `handle`¹⁰³ method runs.

Throws

`NullPointerException` when `initial_area` is null.

`IllegalArgumentException` when `id` is not a valid interrupt id.

12.4.2.3.2 Methods

getHandler(int)

Signature

```
public static
javax.realtime.device.InterruptServiceRoutine getHandler(int interrupt)
```

¹⁰²Section [12.4.2.3.2](#)

¹⁰³Section [12.4.2.3.2](#)

Find the `InterruptServiceRoutine` that is handling a given interrupt.

Parameters

`interrupt` for which to find the `InterruptServiceRoutine`

Returns

the `InterruptServiceRoutine` registered to the given interrupt. `Null` is returned when nothing is registered for that interrupt.

getMaximumInterruptPriority

Signature

```
public static  
int getMaximumInterruptPriority()
```

Retrieve the maximum interrupt priority. It must be greater than or equal to the result of `getMinimumInterruptPriority`¹⁰⁴.

Returns

the maximum interrupt priority.

getMinimumInterruptPriority

Signature

```
public static  
int getMinimumInterruptPriority()
```

Retrieve the minimum interrupt priority. It must be higher than all other priorities provided by the system.

Returns

the minimum interrupt priority.

getInterruptPriority(int)

Signature

```
public static  
int getInterruptPriority(int interruptId)  
throws IllegalArgumentException
```

Get the interrupt priority of a given interrupt.

Throws

¹⁰⁴Section [12.4.2.3.2](#)

`IllegalArgumentException` when there is no interrupt corresponding to `interruptId`

Returns

the priority at which the `handle`¹⁰⁵ method is invoked. The returned value is always greater than `PriorityScheduler.getMaxPriority()`¹⁰⁶.

isRegistered

Signature

```
public final  
boolean isRegistered()
```

A predicate for the registration state.

Returns

true when registered, otherwise false.

register(int)

Signature

```
public  
void register(int interrupt)  
throws RegistrationException
```

Register this interrupt service routine with the system so that it can be triggered.

Parameters

`interrupt` a system dependent identifier for the interrupt.

Throws

`RegistrationException` when this is already registered or some other `InterruptServiceRoutine`¹⁰⁷ is registered for `interrupt`.

unregister

Signature

```
public  
void unregister()
```

¹⁰⁵Section 12.4.2.3.2

¹⁰⁶Section 6.4.2.7.3

¹⁰⁷Section 12.4.2.3

throws `DeregistrationException`

Deregister this interrupt service routine with the system so that it can no longer be triggered.

Throws

`DeregistrationException` when this interrupt service routine is not registered.

handle

Signature

```
protected abstract
void handle()
```

The code to execute for first level interrupt handling. A subclass defines this to give the required behavior. `RawMemory`¹⁰⁸ classes may be used to access the associated device registers and a `Happening`¹⁰⁹ may be triggered for second level interrupt handling.

The code used to implement this method should not block itself for an unbound amount of time or induce a context switch, e.g., sleeping. The effects of unbound blocking and inducing a context switch here are undefined and could result in deadlocking the machine. `Object.notify()` and `Object.notifyAll()` may be called, but `Object.wait()` should not be called.

Unless the overridden method is synchronized, the infrastructure shall provide no synchronization for the execution of this method. When the `javax.realtime.MemoryArea`¹¹⁰ provided at creation is a `javax.realtime.memory.ScopedMemory`¹¹¹, its count is incremented on entry to this method and decremented on exit.

12.4.2.4 RawBufferFactory

Inheritance

```
java.lang.Object
  javax.realtime.device.RawBufferFactory
```

A factory class for generating raw byte buffers. This enables the infrastructure to limit the address ranges from which a buffer may be taken.

¹⁰⁸Section 12.4.1.16

¹⁰⁹Section 12.4.2.1

¹¹⁰Section 11.4.2.3

¹¹¹Section 11.5.3.6

12.4.2.4.1 Constructors

RawBufferFactory(long, long)

Signature

```
public
RawBufferFactory(long base,
                  long size)
throws MemoryInUseException
```

Create a factory for allocating buffers in a particular address range. Whether the address is physical or virtual is system dependent.

Parameters

base is the base address of a memory range for buffer allocation

size is the number of bytes in the memory range

Throws

MemoryInUseException when the memory area provide is already in use by or reserved for a [javax.realtime.MemoryArea](#)¹¹², program code, or other sytem or VM structure.

12.4.2.4.2 Methods

allocateDirectByteBuffer(int)

Signature

```
public
java.nio.ByteBuffer allocateDirectByteBuffer(int capacity)
```

Create a direct byte buffer with the given capacity within the range of this factory.

Parameters

capacity the number of bytes in the buffer.

Returns

¹¹²Section [11.4.2.3](#)

the new buffer.

defineDirectByteBuffer(long, int)

Signature

```
public
java.nio.ByteBuffer defineDirectByteBuffer(long start,
                                             int capacity)

throws RangeOutOfBoundsException
```

Given a range of memory within the allocation area defined by this factory, create a direct byte buffer to represent that memory range.

Parameters

start is the beginning of the memory range

capacity is number of bytes in the range

Throws

RangeOutOfBoundsException when **start** or **start + capacity** extends outside of the allocation area of this factory.

Returns

the new buffer object

inRange(ByteBuffer)

Signature

```
public
boolean inRange(ByteBuffer buffer)
```

Check to see if the buffer's data area is within the range of this factory.

Parameters

buffer to check

Returns

true when and only when buffer's data area is within the range of this factory;
otherwise **false**

addressOf(ByteBuffer)

Signature

```
public
long addressOf(ByteBuffer buffer)
```

Give the location of this buffers data in memory. The address shall be in the address space of the DMA controller.

Parameters

buffer of which to get the address

Returns

the start address of the data range of this buffer

writeFence(ByteBuffer)

Signature

```
public static  
void writeFence(ByteBuffer buffer)
```

Ensures that all changes to the **DirectByteBuffer** buffer by the current thread have been flushed in a manner that makes them visible to other threads (including native threads), and behaves as a volatile store with respect to the Java Memory Model synchronization order.

This method shall invoke a memory barrier operation that is understood by the VM, runtime, native compiler, and platform to provide visibility to all changes to the associated buffer made before its invocation.

Parameters

buffer the byte buffer which will be flushed

readFence(ByteBuffer)

Signature

```
public static  
void readFence(ByteBuffer buffer)
```

Ensures that any previous changes to the memory represented by the given **DirectByteBuffer** by other threads (including native threads) will be visible when it is next accessed by the current thread, and behaves as a volatile load with respect to the Java Memory Model synchronization order.

This method shall invoke a memory barrier operation that is understood by the VM, runtime, native compiler, and platform to provide visibility for any changes to the associated buffer previously flushed with a call to **writeFence(ByteBuffer buffer)**¹¹³ or its native equivalent on the buffer's memory.

Parameters

¹¹³Section [12.4.2.4.2](#)

`buffer` the byte buffer which will be updated

12.4.2.5 RawMemoryFactory

Inheritance

```
java.lang.Object
  javax.realtime.device.RawMemoryFactory
```

This class is the hub of a system that constructs special purpose objects to access particular types and ranges of raw memory. This facility is supported by the `register(RawMemoryRegionFactory)`¹¹⁴ methods. An application developer can use this method to add support for additional memory regions.

Each create method returns an object of the corresponding type, e.g., the `createRawByte(RawMemoryRegion, long, int, int)`¹¹⁵ method returns a reference to an object that implements the `RawByte`¹¹⁶ interface and supports access to the requested type of memory and address range. Each create method is permitted to optimize error checking and access based on the requested memory type and address range.

The usage pattern for raw memory, assuming the necessary factory has been registered, is illustrated by this example.

```
// Get an accessor object that can access memory starting at
// baseAddress, for size bytes.
RawInt memory =
    RawMemoryFactory.createRawInt(RawMemoryFactory.MEMORY_MAPPED_REGION,
                                  address, count, stride, false);
// Use the accessor to load from and store to raw memory.
int loadedData = memory.getInt(someOffset);
memory.setInt(otherOffset, intVal);
```

When an application needs to access a class of memory that is not already supported by a registered factory, the developer must define a memory region by implementing a factory which can create objects to access memory in that region. Thus, the application must implement a factory that implements the `RawMemoryRegionFactory`¹¹⁷ interface.

¹¹⁴Section 12.4.2.5.3

¹¹⁵Section 12.4.2.5.3

¹¹⁶Section 12.4.1.1

¹¹⁷Section 12.4.1.17

A raw memory region factory is identified by a `RawMemoryRegion`¹¹⁸ that is used by each create method, e.g., `createRawByte(RawMemoryRegion, long, int, int)`¹¹⁹, to locate the appropriate factory. The name is not passed to `register(RawMemoryRegionFactory)`¹²¹ as a separate argument, rather the name is provided to `register(RawMemoryRegionFactory)`¹²¹ through the factory's `RawMemoryRegionFactory.getName`¹²² method.

The `register(RawMemoryRegionFactory)`¹²³ method is only used when by application code when it needs to add support for a new type of raw memory.

Whether a give `offset` addresses a high-order or low-order byte of an aligned `short` in memory is determined by the value of the `javax.realtime.RealtimeSystem.BYTE_ORDER`¹²⁴ static byte variable in class `javax.realtime.RealtimeSystem`¹²⁵, the start address of the object, the `offset` given the `stride` of the object. Regardless of the byte ordering, accessor methods for by continue to select bytes starting at `offset` from the base address and continuing toward greater addresses.

The `RawMemory` class enables a realtime program to implement device drivers, memory-mapped I/O, flash memory, battery-backed RAM, and similar low-level software.

A raw memory region cannot contain references to Java objects. Such a capability would be unsafe (since it could be used to defeat Java's type checking) and error prone (since it is sensitive to the specific representational choices made by the Java compiler).

Atomic loads and stores on raw memory are defined in terms of physical memory. This memory may be accessible to threads outside the JVM and to non-programmed access (e.g., DMA). Consequently, atomic access must be supported by hardware. This specification is written with the assumption that all suitable hardware platforms support atomic loads from raw memory for aligned bytes, shorts, and ints. Atomic access beyond the specified minimum may be supported by the implementation.

Storing values into raw memory is more hardware-dependent than loading values. Many processor architectures do not support atomic stores of variables except for aligned stores of the processor's word size. For instance, storing a byte into memory might require reading a 32-bit quantity into a processor register, updating the register to reflect the new byte value, then restoring the whole 32-bit quantity. Changes to other bytes in the 32-bit quantity that take place between the load and

¹¹⁸Section 12.4.2.6

¹¹⁹Section 12.4.2.5.3

¹²⁰Section 12.4.2.5.3

¹²¹Section 12.4.2.5.3

¹²²Section 12.4.1.17.1

¹²³Section 12.4.2.5.3

¹²⁴Section ??

¹²⁵Section 13.3.1.7

the store are lost.

Some processors have mechanisms that can be used to implement an atomic store of a byte, but those mechanisms are often slow and not universally supported.

This class need not support unaligned access to data; but if it does, it is not require the implementation to make such access atomic. Accesses to data aligned on its natural boundary will be atomic if the processor implements atomic loads and stores of that data size.

Except where noted, accesses to raw memory are not atomic with respect to the memory or with respect to schedulable objects. A raw memory region could be updated by another schedulable object, or even unmapped in the middle of an access method, or even *removed* mid method.

The characteristics of raw-memory access are necessarily platform dependent. This specification provides a minimum requirement for the RTSJ platform, but it also supports optional system properties that identify a platform's level of support for atomic raw put and get. The properties represent a four-dimensional sparse array of access type, data type, alignment, and atomicity with boolean values indicating whether that combination of access attributes is atomic. The default value for array entries is false. The dimension are

The true values in the table are represented by properties of the following form. `javax.realtime.atomicaccess_<access>_<type>_<alignment>_atomicity=true` for example,

```
javax.realtime.atomicaccess_read_byte_0_memory=true
```

Table entries with a value of false may be explicitly represented, but since false is the default value, such properties are redundant.

All raw memory access is treated as volatile, and *serialized*. The runtime must be forced to read memory or write to memory on each call to a raw memory objects's getter or setter method, and to complete the reads and writes in the order they appear in the program order.

12.4.2.5.1 Fields

MEMORY_MAPPED_REGION

```
public static final MEMORY_MAPPED_REGION
```

This raw memory name is predefined for use to request access to memory mapped I/O devices.

IO_PORT_MAPPED_REGION

Table 12.1: Property Array

Attribute	Values	Comment
Access type	read, write	
Data type	<ul style="list-style-type: none"> • byte, • short, • int, • long, • float, • double 	
Alignment	0 to 7	<p>For each data type, the possible alignments range from</p> <ul style="list-style-type: none"> • 0 == aligned • to data size - 1 == only the first byte of the data is <i>alignment</i> bytes away from natural alignment.
Atomicity	<ul style="list-style-type: none"> • processor, • smp, • memory 	<ul style="list-style-type: none"> • <i>processor</i> means access is atomic with respect to other schedulable objects on that processor. • <i>smp</i> means that access is <i>processor</i> atomic, and atomic across the processors in an SMP. • <i>memory</i> means that access is <i>smp</i> atomic, and atomic with respect to all access to the memory, including DMA hardware.

```
public static final IO_PORT_MAPPED_REGION
```

This raw memory name is predefined for use to request access to I/O device space implemented by processor instructions, such as the x86 `in` and `out` instructions.

12.4.2.5.2 Constructors

RawMemoryFactory

Signature

```
public
RawMemoryFactory()
```

Create an empty factory. For a factory with support for the platform defined [RawMemoryRegion](#)¹²⁶s, use [getDefaultFactory](#)¹²⁷ instead.

12.4.2.5.3 Methods

getDefaultFactory

Signature

```
public static
javax.realtime.device.RawMemoryFactory getDefaultFactory()
```

Get the factory with support for the platform defined regions.

Returns

the platform defined factory

register(RawMemoryRegionFactory)

Signature

¹²⁶Section [12.4.2.6](#)

¹²⁷Section [12.4.2.5.3](#)

```
public
void register(RawMemoryRegionFactory factory)
throws RegistrationException
```

Add support for a new memory region

Parameters

`factory` is the [RawMemoryRegionFactory¹²⁸](#) to use for creating [RawMemory¹²⁹](#) objects for the the [RawMemoryRegion¹³⁰](#) it makes available.

Throws

`RegistrationException` when the `RawMemoryRegion` of `factory` already has a factory registered.

deregister(RawMemoryRegionFactory)

Signature

```
public
void deregister(RawMemoryRegionFactory factory)
throws DeregistrationException
```

Remove support for a new memory region

Parameters

`factory` is the [RawMemoryRegionFactory¹³¹](#) to make unavailable.

Throws

`RegistrationException` when the factory is not registered.

createRawByte(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawByte createRawByte(RawMemoryRegion region,
                                              long base,
                                              int count,
                                              int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
```

¹²⁸Section [12.4.1.17](#)

¹²⁹Section [12.4.1.16](#)

¹³⁰Section [12.4.2.6](#)

¹³¹Section [12.4.1.17](#)

MemoryTypeConflictException,
UnsupportedRawMemoryRegionException

Create an instance of a class that implements [RawByte](#)¹³² and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawByte * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawByte](#)¹³³ and supports access to the specified range in the memory region.

createRawByteReader(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawByteReader createRawByteReader(RawMemoryRegion region,
                                                         long base,
                                                         int count,
                                                         int stride)
```

¹³²Section [12.4.1.1](#)

¹³³Section [12.4.1.1](#)

throws `SecurityException`,
`OffsetOutOfBoundsException`,
`SizeOutOfBoundsException`,
`MemoryTypeConflictException`,
`UnsupportedRawMemoryRegionException`

Create an instance of a class that implements `RawByteReader`¹³⁴ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawByteReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

`base` The starting physical address accessible through the returned instance.

`count` The number of memory elements accessible through the returned instance.

`stride` The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawByteReader`¹³⁵ and supports access to the specified range in the memory region.

createRawByteWriter(RawMemoryRegion, long, int, int)

Signature

¹³⁴Section 12.4.1.2

¹³⁵Section 12.4.1.2

```

public
    javax.realtime.device.RawByteWriter createRawByteWriter(RawMemoryRegion region,
                                                            long base,
                                                            int count,
                                                            int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        MemoryTypeConflictException,
        UnsupportedRawMemoryRegionException

```

Create an instance of a class that implements [RawByteWriter](#)¹³⁶ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawByteWriter* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawByteWriter](#)¹³⁷ and supports access to the specified range in the memory region.

¹³⁶Section [12.4.1.3](#)

¹³⁷Section [12.4.1.3](#)

createRawShort(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawShort createRawShort(RawMemoryRegion region,
                                              long base,
                                              int count,
                                              int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        MemoryTypeConflictException,
        UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements [RawShort](#)¹³⁸ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawShort * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

¹³⁸Section [12.4.1.18](#)

an object that implements [RawShort](#)¹³⁹ and supports access to the specified range in the memory region.

createRawShortReader(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawShortReader createRawShortReader(RawMemoryRegion region,
                                                         long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements [RawShortReader](#)¹⁴⁰ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawShortReader * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

¹³⁹Section [12.4.1.18](#)

¹⁴⁰Section [12.4.1.19](#)

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawShortReader**¹⁴¹ and supports access to the specified range in the memory region.

createRawShortWriter(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawShortWriter createRawShortWriter(RawMemoryRegion region,
                                                           long base,
                                                           int count,
                                                           int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements **RawShortWriter**¹⁴² and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawShortWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

¹⁴¹Section 12.4.1.19

¹⁴²Section 12.4.1.20

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawShortWriter**¹⁴³ and supports access to the specified range in the memory region.

createRawInt(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawInt createRawInt(RawMemoryRegion region,
                                           long base,
                                           int count,
                                           int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements **RawInt**¹⁴⁴ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawInt * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

¹⁴³Section 12.4.1.20

¹⁴⁴Section 12.4.1.10

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when **base** is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawInt`¹⁴⁵ and supports access to the specified range in the memory region.

createRawIntReader(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawIntReader createRawIntReader(RawMemoryRegion region,
                                                    long base,
                                                    int count,
                                                    int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements `RawIntReader`¹⁴⁶ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawIntReader* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

¹⁴⁵Section 12.4.1.10

¹⁴⁶Section 12.4.1.11

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawIntReader](#)¹⁴⁷ and supports access to the specified range in the memory region.

createRawIntWriter(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawIntWriter createRawIntWriter(RawMemoryRegion region,
                                                       long base,
                                                       int count,
                                                       int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements [RawIntWriter](#)¹⁴⁸ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**.

¹⁴⁷Section [12.4.1.11](#)

¹⁴⁸Section [12.4.1.12](#)

The actual extent of the memory addressed by the object is `stride * size of RawIntWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when **base** is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawIntWriter`¹⁴⁹ and supports access to the specified range in the memory region.

createRawLong(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawLong createRawLong(RawMemoryRegion region,
                                             long base,
                                             int count,
                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
```

¹⁴⁹Section 12.4.1.12

UnsupportedRawMemoryRegionException

Create an instance of a class that implements [RawLong](#)¹⁵⁰ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawLong* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawLong](#)¹⁵¹ and supports access to the specified range in the memory region.

createRawLongReader(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawLongReader createRawLongReader(RawMemoryRegion region,
                                                         long base,
                                                         int count,
                                                         int stride)
```

¹⁵⁰Section [12.4.1.13](#)

¹⁵¹Section [12.4.1.13](#)

throws `SecurityException`,
`OffsetOutOfBoundsException`,
`SizeOutOfBoundsException`,
`MemoryTypeConflictException`,
`UnsupportedRawMemoryRegionException`

Create an instance of a class that implements `RawLongReader`¹⁵² and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawLongReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

`base` The starting physical address accessible through the returned instance.

`count` The number of memory elements accessible through the returned instance.

`stride` The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawLongReader`¹⁵³ and supports access to the specified range in the memory region.

createRawLongWriter(RawMemoryRegion, long, int, int)

Signature

¹⁵²Section 12.4.1.14

¹⁵³Section 12.4.1.14

```

public
    javax.realtime.device.RawLongWriter createRawLongWriter(RawMemoryRegion region,
                                                            long base,
                                                            int count,
                                                            int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        MemoryTypeConflictException,
        UnsupportedRawMemoryRegionException

```

Create an instance of a class that implements [RawLongWriter](#)¹⁵⁴ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawLongWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawLongWriter](#)¹⁵⁵ and supports access to the specified range in the memory region.

¹⁵⁴Section [12.4.1.15](#)

¹⁵⁵Section [12.4.1.15](#)

createRawFloat(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawFloat createRawFloat(RawMemoryRegion region,
                                              long base,
                                              int count,
                                              int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        MemoryTypeConflictException,
        UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements [RawFloat](#)¹⁵⁶ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawFloat * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

¹⁵⁶Section [12.4.1.7](#)

an object that implements [RawFloat](#)¹⁵⁷ and supports access to the specified range in the memory region.

createRawFloatReader(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawFloatReader createRawFloatReader(RawMemoryRegion region,
                                                         long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements [RawFloatReader](#)¹⁵⁸ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawFloatReader * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

¹⁵⁷Section [12.4.1.7](#)

¹⁵⁸Section [12.4.1.8](#)

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawFloatReader**¹⁵⁹ and supports access to the specified range in the memory region.

createRawFloatWriter(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawFloatWriter createRawFloatWriter(RawMemoryRegion region,
                                                            long base,
                                                            int count,
                                                            int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        MemoryTypeConflictException,
        UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements **RawFloatWriter**¹⁶⁰ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawFloatWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

¹⁵⁹Section 12.4.1.8

¹⁶⁰Section 12.4.1.9

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawFloatWriter**¹⁶¹ and supports access to the specified range in the memory region.

createRawDouble(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawDouble createRawDouble(RawMemoryRegion region,
                                                long base,
                                                int count,
                                                int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements **RawDouble**¹⁶² and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawDouble * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

¹⁶¹Section 12.4.1.9

¹⁶²Section 12.4.1.4

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawDouble`¹⁶³ and supports access to the specified range in the memory region.

`createRawDoubleReader(RawMemoryRegion, long, int, int)`

Signature

```
public
javax.realtime.device.RawDoubleReader createRawDoubleReader(RawMemoryRegion region,
                                                             long base,
                                                             int count,
                                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements `RawDoubleReader`¹⁶⁴ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawDoubleReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

¹⁶³Section 12.4.1.4

¹⁶⁴Section 12.4.1.5

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawDoubleReader](#)¹⁶⁵ and supports access to the specified range in the memory region.

createRawDoubleWriter(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawDoubleWriter createRawDoubleWriter(RawMemoryRegion region,
                                                             long base,
                                                             int count,
                                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Create an instance of a class that implements [RawDoubleWriter](#)¹⁶⁶ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The

¹⁶⁵Section [12.4.1.5](#)

¹⁶⁶Section [12.4.1.6](#)

actual extent of the memory addressed by the object is `stride * size of RawDoubleWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when **base** is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawDoubleWriter`¹⁶⁷ and supports access to the specified range in the memory region.

12.4.2.6 RawMemoryRegion

Inheritance

`java.lang.Object`

`javax.realtime.device.RawMemoryRegion`

`RawMemoryRegion` is a class for typing raw memory regions. It is returned by the `RawMemoryRegionFactory.getRegion`¹⁶⁸ methods of the raw memory region factory classes, and it is used with methods such as `RawMemoryFactory.createRawByte(RawMemoryRegion, long, int, int)`¹⁶⁹ and `RawMemoryFactory.createRawDouble(RawMemoryRegion,`

¹⁶⁷Section 12.4.1.6

¹⁶⁸Section 12.4.1.17.1

¹⁶⁹Section 12.4.2.5.3

`long, int, int)`¹⁷⁰ methods to identify the region from which the application wants to get an accessor instance.

12.4.2.6.1 Methods

getRegion(String)

Signature

```
public static
javax.realtime.device.RawMemoryRegion getRegion(String name)
```

Get a region type when it already exists or creates a new one.

Parameters

name of the region

Returns

the region type object.

isRawMemoryRegion(String)

Signature

```
public static
boolean isRawMemoryRegion(String name)
```

Ask whether or not there is a memory region type of a given name.

Parameters

name for which to search

Returns

true when there is one and **false** otherwise.

getName

Signature

```
public final
java.lang.String getName()
```

¹⁷⁰Section 12.4.2.5.3

Obtains the name of this region type.

Returns

the region types name

toString

Signature

```
public final  
java.lang.String toString()
```

Gets a printable representation for a Region.

Returns

the name of this memory region type.

12.5 Rationale

12.5.1 Raw Memory

Raw memory in the RTSJ refers to any memory in which only objects of primitive types can be stored; *Java objects or their references cannot be stored in raw memory*. 2.0 of specification provides two categories:

- memory that is used to access memory-mapped device registers, and
- logical memory that can be used to access port-based device registers.

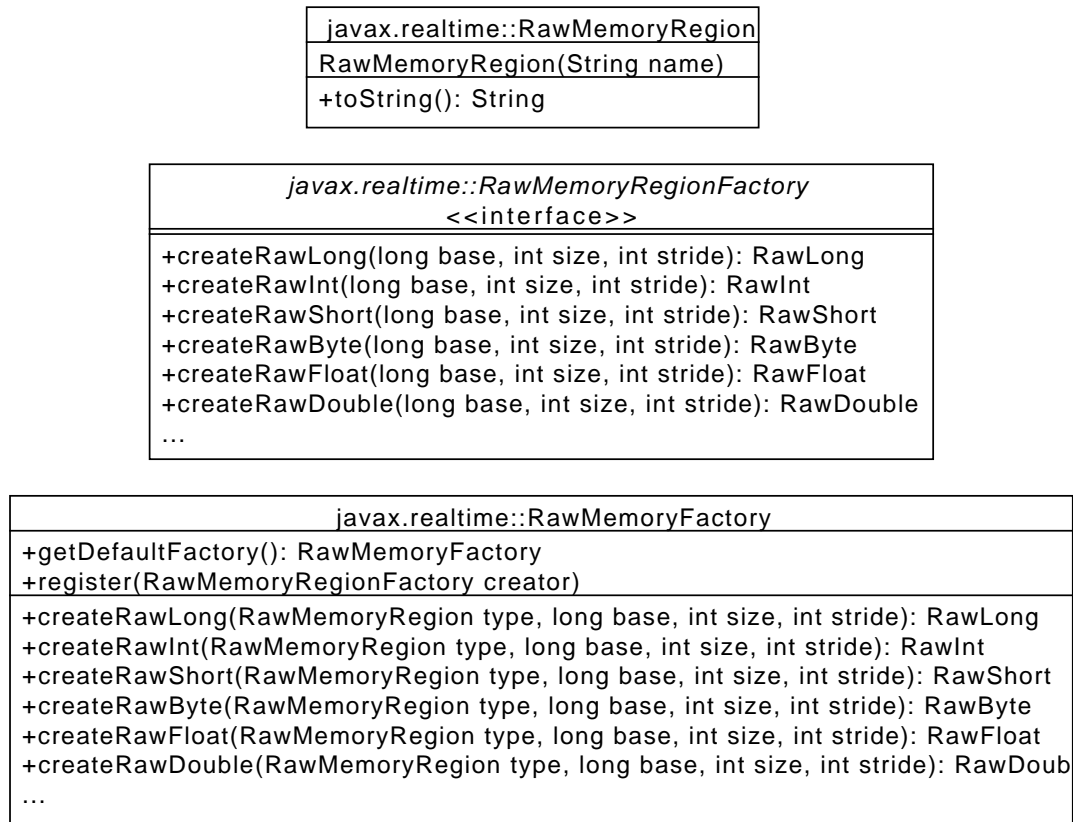
Each of these categories of memory is represented by an instance of **RawMemoryRegion**. In addition, the application can define other regions outside these two, either for accessing devices registers in some other address space or for other purposes, such as emulating device access.

Java's primitive types are partitioned into two groups: integral (short, int, long, byte) and real (float, double) types, including arrays of each type. For integral types, individual interfaces are also defined to facilitate greater type security during access. Objects that support these interfaces are created by factory methods, which again have predefined interfaces. Such objects are called *accessor* objects as they encapsulates the access protocol to the raw memory.

Control over all these objects is managed by the **RawMemoryFactory** class that provides a set of static methods, as shown in Figure 12.5. There are two groups of methods, those that

- enable a factory to be registered, and

Figure 12.5: Creating Raw Memory Accessors



- request the creation of *accessor* object for a particular memory type at a particular address.

The latter consists of methods to create Java-primitive-type accessor objects, which will throw exceptions if the appropriate addresses are not on correct boundaries to enable the underlying machine instructions to be used without causing hardware exceptions (e.g., `createRawByteReader`).

As with interrupt handling, some realtime JVMs may not be able to support all of the memory categories. However, the expectation is that for all supported categories, they will also provide and register the associated factories for object creation.

For the case of `IO_PORT_MAPPED` raw memory, the accessor objects will need to arrange to execute the appropriate machine instructions to access the device registers.

Consider, the simple case where a device has a two device registers: a control/status register that is a 32 bits integer, and a data register that is a 64 bits long.

The registers have been memory mapped to locations: 0x20 and 0x24 respectively. Assuming the realtime JVM has registered a factory for the `IO_PORT_MAPPED_REGION` raw memory name, then the following code will create the objects that facilitate the memory access

```

1 RawMemoryFactory factor = RawMemoryFactory.getDefaultFactory();
2 RawInt controlReg =
3   factory.createRawInt(RawMemoryFactory.IO_PORT_MAPPED_REGION, 0x20);
4 RawLong dataReg =
5   factory.createRawLong(RawMemoryFactory.IO_PORT_MAPPED_REGION, 0x24);

```

The above definitions reflect the structure of the actual registers. The JVM will check that the memory locations are on the correct boundaries and that they can be accessed without any hardware exceptions being generated. If they cannot, the create methods will throw an appropriate exceptions. If successfully created, all future access to the `controlReg` and `dataReg` will be exception free. The registers can be manipulated by calling the appropriate methods, as in the following example.

```

1 dataReg.put(1);
2   // where 1 is of type long and is data to be sent to the device
3 controlReg.put(i);
4   // where i is of type int and is the command to the device

```

In the general case, programmers themselves may create their own memory categories and provide associated factories (that may use the implementation-defined factories). These factories are written in Java and are, therefore, constrained by what the language allows them to do. Typically, they will use the JVM-supplied raw memory types to facilitate access to a device's external memory.

Open issue: Andy: is the following still true? **End of open issue** In addition to the above facilities, the RTSJ also supports the notion of removable memory. When this memory is inserted or removed, an asynchronous event can be set up to fire, thereby alerting the application that the device has become active. Of course, any removable memory has to be treated with extreme caution by the realtime JVM. Hence, the RTSJ allows it only to be accessed as a raw memory device. An example of these latter facilities will be given in Section [12.5.3](#).

12.5.1.1 Direct memory access

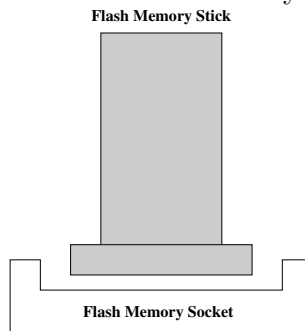
DMA requires access to memory out side of the heap. It is often crucial for performance in embedded systems; however, it does cause problems both from a realtime analysis perspective and from a JVM-implementation perspective. The latter is the primary concern here.

There are a few crucial points to note about DMA and the RTSJ.

- The RTSJ does not address issues of persistent objects; so the input and output of Java objects to devices (other than by using the Java serialization mechanism) is not supported.
- The RTSJ requires that RTSJ programs can be compiled by regular Java compilers. Different bytecode compilers (and their supporting JVM) use different representation for objects. Java arrays (even of primitive types) are objects, and the data they contain might not be stored in contiguous memory.
- The package `java.nio.channels` provides a mechanism for I/O that was not specifically designed for DMA, but provides an applicable pattern for it.

For these reasons, without explicit knowledge of the compiler and JVM, allowing any DMA into any RTSJ memory area is a very dangerous action; therefore, the RTSJ provides some special support for DMA. Unfortunately, it would be difficult to find a general pattern to fit all DMA controllers. With raw memory and raw byte buffers, one could construct a higher level API that would cover most DMA controllers, but there will always odd cases that would still not fit the general pattern, especially for embedded systems. For this reason, only this low level API is provided.

Figure 12.6: Flash memory device



12.5.2 Interrupt Handling

Handling interrupts is a necessary part of many embedded systems. Interrupt handlers have traditionally been implemented in assembler code or C. With the growing popularity of high-level concurrent languages, there has been interest in better integration between the interrupt handling code and the application. Ada, for example, allows a “protected” procedure to be called directly from an interrupt [3].

Regehr [7] defines the terms used for the core components of interrupts and their handlers as follows.

- *Interrupt*—a hardware supported asynchronous transfer of control mechanism initiated by an event external to the processor. Control of the processor is transferred through an interrupt vector.
- *Interrupt vector*—a dedicated (or configurable) location that specifies the location of an interrupt handler.
- *Interrupt handler*—code that is reachable from the interrupt vector.
- *An interrupt controller*—a peripheral device that manages interrupts for the processor.

He further identifies the following problems with programming interrupt-driven software on single processors:

- *Stack overflow*—the difficulty determining how much call-chain stack is required to handle an interrupt. The problem is compounded if the stack is borrowed from the currently executing thread or process.
- *Interrupt overload*—the problem of ensuring that non-interrupt driven processing is not swamped by unexpected or misbehaving interrupts.
- *Real-time analysis*—the need to have appropriate schedulability analysis models to bound the impact of interrupt handlers.

The problems above are accentuated in multiprocessor systems where interrupts can be handled globally. Fortunately, many multiprocessor systems allow interrupts to be bound to particular processors. For example, the ARM Cortex A9-MPCore supports the Arm Generic Interrupt Controller¹⁷¹. This enables a target list of CPUs to be specified for each hardware interrupt. Software generated interrupts can also be sent to the list or set up to be delivered to all but the requesting CPU or only the requesting CPU.

Regehr's problems are all generic and can be solved irrespective of the language used to implement the handlers. In general they can be addressed by a combination of techniques.

- *Stack overflow*—static analysis techniques can usually be used to determine the worst-case stack usage of all interrupt handlers. If stack is borrowed from the executing thread then this amount must be added to the worst-case stack usage of all threads.
- *Interrupt overload*—this is typically managed by aperiodic server technology in combination with interrupt masking (see Section 13.6 of [3]).
- *Real-time analysis*—again this can be catered for in modern schedulability analysis techniques, such as response-time analysis (see Section 14.6 of [3]).

From a RTSJ perspective, the following distinctions are useful

- The *first-level interrupt handlers* are the code that the platform executes in response to the hardware interrupts (or traps). A first-level interrupt is assumed to be executed at an execution eligibility (priority) and by a processor dictated

¹⁷¹ See <http://infocenter.arm.com/help/index.jsp?topic=/com.arm.doc.ddi0375a/Cegbfjhf.html>

by the underlying platform (which may be controllable at the platform level). On some RTSJ implementations it will not be possible to write Java code for these handlers. Implementations that do enable Java-level handlers may restrict the code that can be written. For example, the handler code should not suspend itself or throw unhandled exceptions. The RTSJ 2.0 optional `InterruptServiceRoutine` class supports first level interrupt handling.

- The *external event handler* is the code that the JVM executes as a result of being notified that an external event (be it an operating system signal, an ISR or some other program) is targeted at the RTSJ application. The programmer should be able to specify the processor affinity and execution eligibility of this code. In RTSJ 2.0, all external events are represented by instances of the `Happening` interface. Every happening has an associated dispatcher which is responsible for the initial response to an occurrence of the event.
- A happening dispatcher is able to find one or more associated RTSJ asynchronous events and fire them. This then releases the associated asynchronous event handlers.

12.5.3 An Illustrative Example

Consider an embedded system that has a simple flash memory device that supports a single type of removable flash memory stick, as illustrated in Figure 12.6.

When the memory stick is inserted or removed, an interrupt is generated. This interrupt is known to the realtime JVM. The interrupt is also generated when operations requested on the device are completed. For simplicity, it is assumed that realtime JVM has mapped this interrupt to an external happening called `Flash-Happening` with a default happening dispatcher.

The example illustrates how

1. a programmer can use the RTSJ facilities to write a device handler,
2. a factory class can be constructed and how the accessor objects police the access,
3. removable memory is handled.

The flash memory device is accessed via several associated registers, which are shown in Table 12.2. These have all been memory mapped to the indicated locations.

12.5.3.1 Software architecture

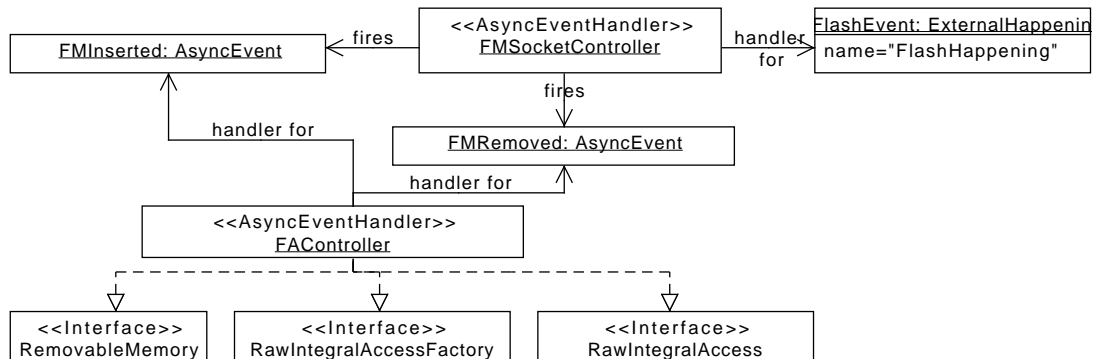
There are many ways in which the software architecture for the example could be constructed. Here, for simplicity of representation, an architecture is chosen with a minimal number of classes. It is illustrated in Figure 12.7. There are three key components.

Table 12.2: Device registers

Register	Location	Bit Positions	Values
Command	0x20	0	0 = Disable device, 1 = Enable device
		4	0 = Disable interrupts, 1 = Enable interrupts
		5-8	1 = Read byte, 2 = Write byte 3 = Read short, 4 = Write short 5 = Read int, 6 = Write int 7 = Read long, 8 = Write long
		9	0 = DMA Read, 1 = DMA
		31-63	Offset into flash memory
Data	0x28	0-63	Simple data or memory address if DMA
Length	0x30	0-31	Length of data transfer
Status	0x38	0	1 = Device enabled
		3	1 = Interrupts enabled
		4	1 = Device in error
		5	1 = Transfer complete
		6	1 = Memory stick present 0 = Memory stick absent
		7	1 = Memory stick inserted 0 = Memory stick removed

- **FlashHappening**—This is the external happening that is associated with the flash device’s interrupt. The **RTSJ** will provide a default dispatcher, which will fire the asynchronous event when the interrupt occurs.
- **FMSocketController**—This is the object that encapsulates the access to the flash memory device. In essence, it is the device driver; it is also the handler for the **FlashHappening** and is responsibly for firing the **FMInserted** and **FMRemoved** asynchronous events.
- **FAController**—This is the object that controls access to the flash memory, it
 - acts as the factory for the creating objects that will facilitate access to the flash memory itself (using the mechanisms provided by the **FMSocketController**),
 - is the asynchronous event handler that responds to the firing of the **FMInserted** and **FMRemoved** asynchronous events, and
 - also acts as the accessor object for the memory.

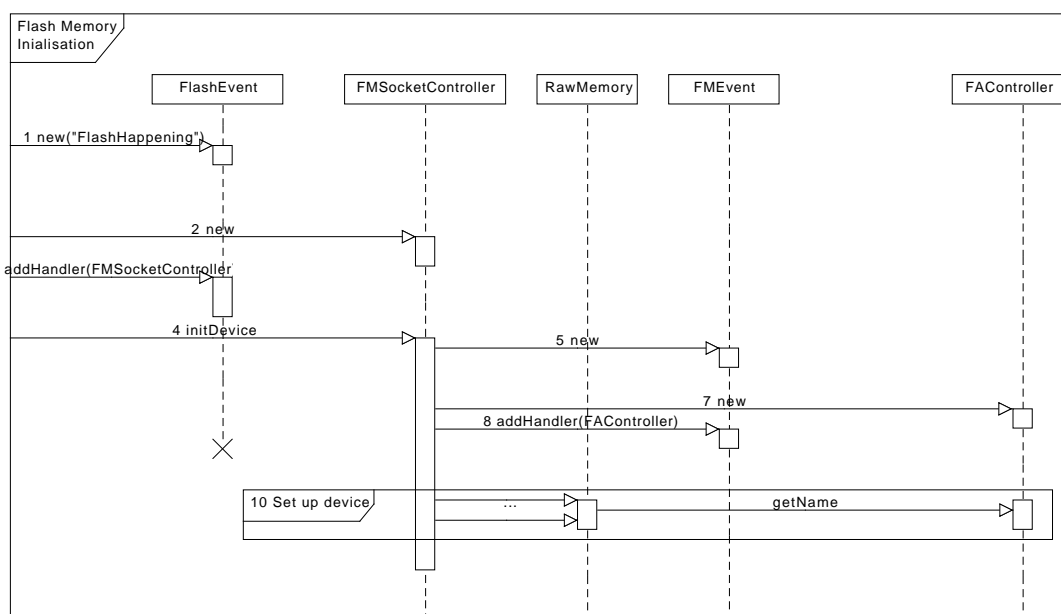
Figure 12.7: Flash memory classes



12.5.3.2 Device initialization

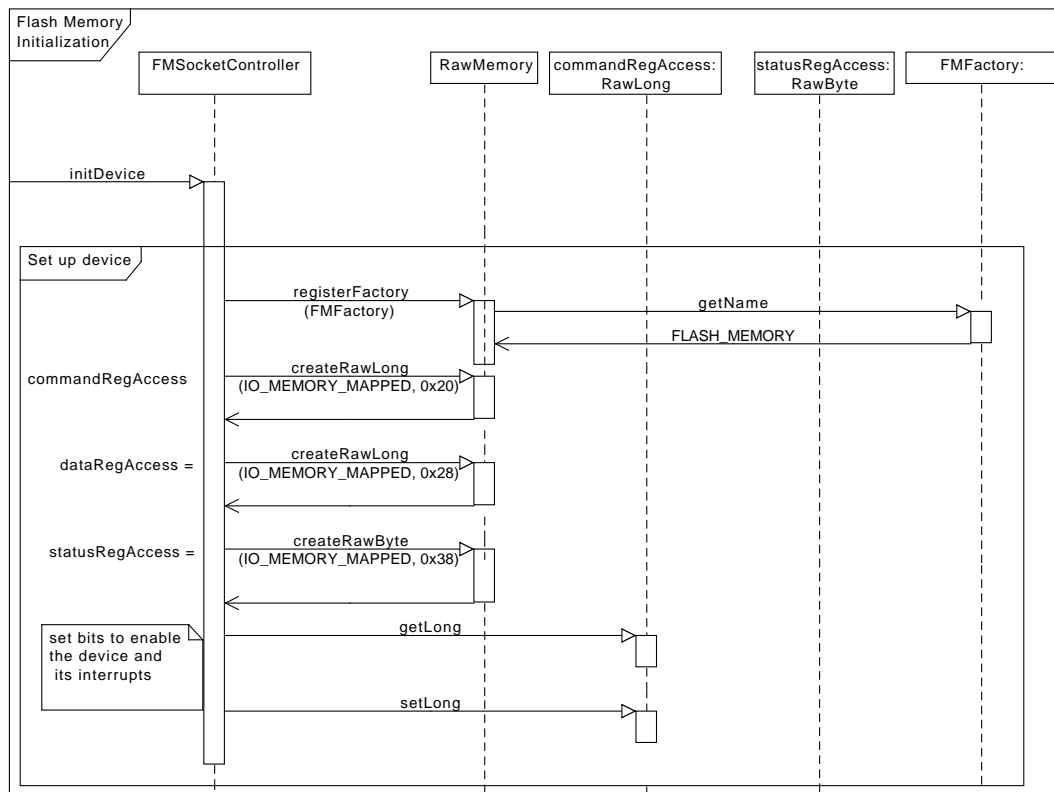
Figure 12.8 shows the sequence of operations that the program must perform to initialize the flash memory device. The main steps are as follows.

Figure 12.8: Sequence diagram showing initialization operations



- 1 The external happening (**FlashEvent**) associated with the flash happening must be created.

Figure 12.9: Sequence diagrams showing operations to initialize the hardware device



2-3 The (**FMSocketController**) object is created and added as a handler for **FlashEvent**.

4 An initialization method is called (**initDevice**) to perform all the operations necessary to configure the infrastructure and initialize the hardware device.

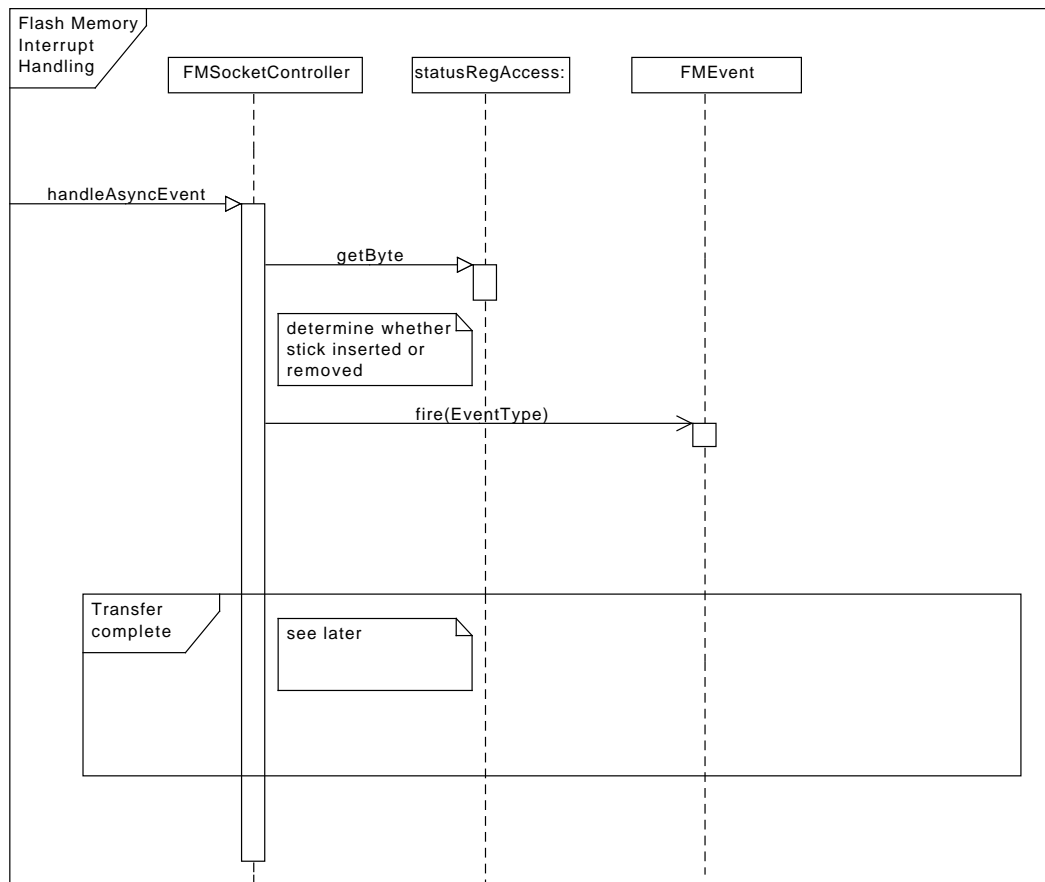
5-6 Two new asynchronous events are created to represent insertion and removal of the flash memory stick.

7-9 The **FAController** class is created. It is added as the handler for the two events created in steps 5 and 6.

10 Setting up the device and registering the factory is shown in detail in Figure 12.9. It involves: registering the **FAController** object via the static methods in the **RawMemory** class, and creating and using the JVM-supplied factory to access the memory-mapped I/O registers.

12.5.3.3 Responding to external happenings

In the example, interrupts are handled by the JVM, which turns them into an external happening. The application code that indirectly responds to the happening

Figure 12.10: The `FMSocketController.handleAsync` method

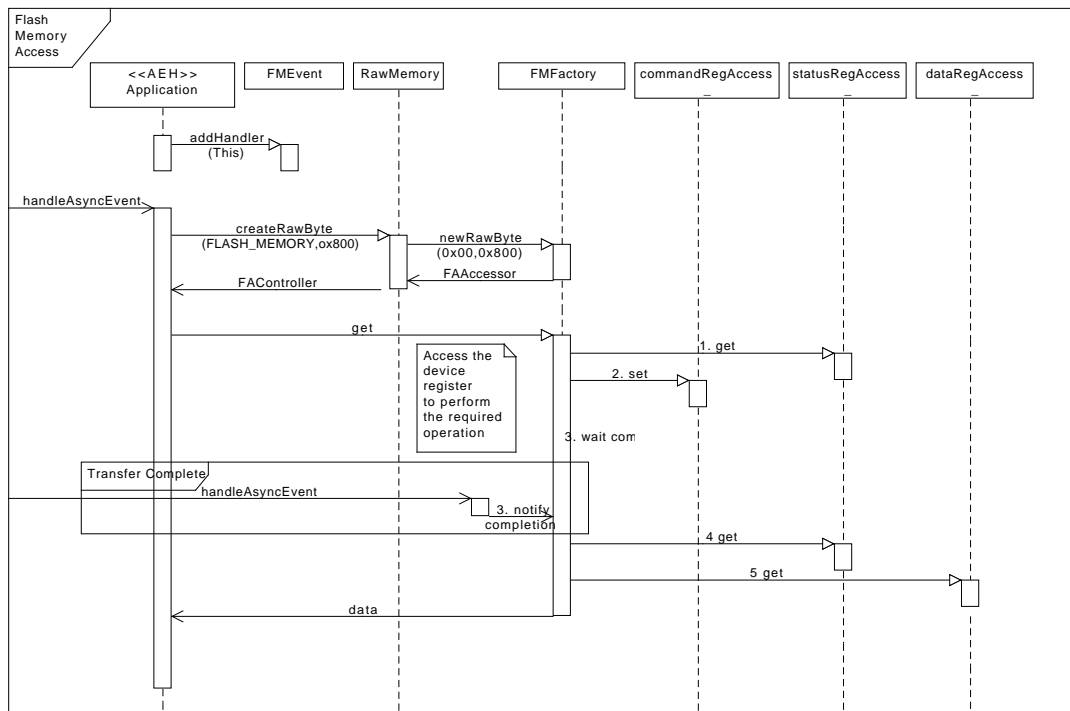
is provided in the `handleAsyncEvent` method in the `FMSocketController` object. Figure 12.10 illustrates the approach. In this example, the actions in response to the *memory stick inserted* and *memory stick removed* flash events is simply shown as the execution of the `FMInserted` and `FMRemoved` handlers. These will inform the application. The memory accessor classes themselves will ensure that the stick is present when performing the required application accesses.

12.5.3.4 Access to the flash controller's device registers

Figure 12.11 shows the sequence of events that the application follows. First it must register a handler with the `FMInserted` asynchronous event. Here, the application itself is an asynchronous event handler. When this is released, the memory has been inserted.

In this simple example, the application simply reads a byte from an offset within the memory stick. It, therefore, creates an accessor to access the data. When

Figure 12.11: Application usage



this has been returned (it is the **FAController** itself), the application can now call the **get** method (called *FA get*, in the following, for clarity). This method must implement the sequence of raw memory access on the device's registers to perform the operation. In Figure 12.11, they are as follows.

1. *FA get* calls the **get** method of the status register's accessor object. This can check to make sure that the flash memory is present (bit 6, as shown in Table 12.2). If it is not, an exception can be thrown.
2. Assuming the memory is present, it then sets the control register with the offset required (bits 31–63, as shown in Table 12.2) and sets the read byte request bit (bits 5–8, as shown in Table 12.2).
3. The *FA get* method must then wait for indication that the requested operation has been completed by the device. This is detected by the **handleAsyncEvent** method of the **FMController**, which performs the necessary notify.
4. Once notified of completion, the *FA get* method, again reads the status register to make sure there were no errors on the device (bit 4 in Table 12.2) and that the memory is still present
5. The *FA get* then reads the data register to get the requested data, which it returns.

Chapter 13

System and Options

13.1 Overview

Implementations of this specification run on many operating systems and this specification itself supports several variants, therefore a means of querying and handling this variation is required. For instance, though many realtime operating systems support the POSIX standard, many do not as well. Even the ones that do vary in their degree of compliance. POSIX provides a well defined means of signalling other processes and receiving signals from them, therefore one would like to be able to use this facility when available. The specification defines classes to help manage these differences providing the following:

- a class that contains operations and semantics that affect the entire system;
- the security semantics required by the additional features in the entirety of this specification, which are additional to those required by implementations of the Java Language Specification; and
- a common idiom for binding POSIX signals to instances of `AsyncEventHandler` when POSIX signals are available on the underlying platform.

The `RealtimeSecurity` class provides security primarily for physical memory access.

13.2 Semantics

There are four classes with semantics that do not fall into other categories: `RealtimeSystem`, `RealtimeSecurity`, `POISIXSignal`, and `POSIXRealtimeSignal`. Their overall semantics is detailed below. Afterwards, semantics that apply to methods, constructors, and fields of these classes are provided as well.

13.2.0.5 RealtimeSystem

RealtimeSystem is a required class, which provides basic information about the RTSJ extensions supported by the system. Via this class, a program can query the default monitor policy, the realtime security manager, and other realtime properties of the system. Starting from version 2, a program can also ask what modules are supported. Determining the current version is supported by a system property. If an application call the method, `System.getProperty("javax.realtime.version")`, the return value will be a string of the form, "x.y.z". Where 'x' is the major version number and 'y' and 'z' are minor version numbers. These version numbers state to which version of the RTSJ the underlying implementation claims conformance. The first release of the RTSJ, dated 11/2001, was numbered 1.0.0. A release conforming to this version of the specification should return the string "2.0.0".

13.2.0.6 RealtimeSecurity

The **RealtimeSecurity** class controls access to key realtime features. Particularly critical is access to memory outside the heap. Core RTSJ features also have security checks. This should enable an application to restrict the use of the RTSJ, particularly for dynamically loaded code. Detailed information is provided in the class documentation below.

13.2.0.7 POSIX Signals

The **POSIXSignal** class represents POSIX signals and is required on platforms that provide POSIX signals. As a **Happening**, it is a subclass of **AsyncEvent** and implements **ActiveEvent**. Unlike **Happening**, it cannot be instantiated by the user. Instead, an instance exists for each POSIX signal defined on the system. They can be retrieved either by name or number using the `POSIXSignal.get(int)` and `POSIXSignal.get(String)` methods.

13.2.0.8 POSIX Realtime Signals

The **POSIXRealtimeSignal** class represents POSIX realtime events. It is also implements **ActiveEvent**, but is a subclass of **AsyncLongEvent**, so that it can pass the data sent with its signal. As with **POSIXSignal**, it cannot be instantiated by the user, rather an instance exists for each POSIX signal defined on the system, which can be retrieved either by name or number using the `POSIXRealtimeSignal.get(int)` and `POSIXRealtimeSignal.get(String)` methods.

13.3 Package javax.realtime

13.3.1 Classes

13.3.1.1 GarbageCollector

Inheritance

java.lang.Object
 [javax.realtime.GarbageCollector](#)

The system shall provide dynamic and static information characterizing the temporal behavior and imposed overhead of any garbage collection algorithm provided by the system. This information shall be made available to applications via methods on subclasses of `GarbageCollector`. Implementations are allowed to provide any set of methods in subclasses as long as the temporal behavior and overhead are sufficiently categorized. The implementations are also required to fully document the subclasses.

A reference to the garbage collector responsible for heap memory is available from [RealtimeSystem.currentGC\(\)](#)¹.

13.3.1.1.1 Methods

getPreemptionLatency

Signature

```
public abstract  
    javax.realtime.RelativeTime getPreemptionLatency()
```

Preemption latency is a measure of the maximum time a schedulable object may have to wait for the collector to reach a preemption-safe point.

Instances of [NoHeapRealtimeThread](#)² and async event handlers with the no-heap option preempt garbage collection immediately, but other schedulables must wait until the collector reaches a preemption-safe point. For many garbage collectors the only preemption safe point is at the end of garbage collection, but an implementation of the garbage collector could permit a schedulable to preempt garbage collection before it completes. The `getPreemptionLatency` method gives such a

¹Section [13.3.1.7.2](#)

²Section [15.3.3.4](#)

garbage collector a way to report the worst-case interval between release of a schedulable during garbage collection, and the time the schedulable starts execution or gains full access to heap memory, whichever comes later.

Returns

The worst-case preemption latency of the garbage collection algorithm represented by `this`. The returned object is allocated in the current allocation context. When there is no constant that bounds garbage collector preemption latency, this method shall return a relative time with `Long.MAX_VALUE` milliseconds. The number of nanoseconds in this special value is unspecified.

13.3.1.2 POSIXRealtimeSignal

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncLongEvent
      javax.realtime.POSIXRealtimeSignal
```

Interfaces

```
ActiveEvent
```

A `ActiveEvent`³ subclass for defining a POSIX realtime signal.

13.3.1.2.1 Methods

isPOSIXRealtimeSignal(String)

Signature

```
public static
boolean isPOSIXRealtimeSignal(String name)
```

Determine if a signal with a given name is registered.

Parameters

name of the signal

Returns

true when a signal with the given name is registered

³Section 8.4.1.1

getId(String)

Signature

```
public static  
int getId(String name)
```

Get the ID of a registered signal.

Parameters

name of the signal for which to search

Returns

the ID of the signal named by **name**

get(String)

Signature

```
public static  
javax.realtime.POSIXRealtimeSignal get(String name)
```

Get the registered realtime signal with the given name.

Parameters

name of the signal to get.

Returns

the registered signal with name or null.

get(int)

Signature

```
public static  
javax.realtime.POSIXRealtimeSignal get(int id)
```

Get the realtime signal corresponding to a given id.

Parameters

id of a registered signal

Returns

the signal corresponding to id.

getId

Signature

```
public  
int getId()
```

Get the name of this realtime signal.

Returns

its name.

getName

Signature

```
public final  
java.lang.String getName()
```

Get the name of this signal.

Returns

the name of this signal.

getDispatcher

Signature

```
public  
javax.realtime.POSIXRealtimeSignalDispatcher getDispatcher()
```

isActive

Signature

```
public  
boolean isActive()
```

Determine the activation state of this signal, i.e., it has been started.

Returns

true when active, **false** otherwise.

isRunning

Signature

```
public  
boolean isRunning()
```

Determine the firing state (releasing or skipping) of this signal, i.e., it is active and enabled.

Returns

`true` when releasing, `false` when skipping.

start

Signature

```
public final synchronized
void start()
throws IllegalStateException
```

Start this `POSIXRealtimeSignal`, i.e., change to a running state. A running realtime signal is a source of activation when in a scoped memory and is a member of the root set when in the heap. A running realtime signal can be triggered.

[See Section stop\(\)](#)

Throws

`IllegalStateException` when this `POSIXRealtimeSignal` has already been started.

start(boolean)

Signature

```
public final synchronized
void start(boolean disabled)
throws IllegalStateException
```

Start this `POSIXRealtimeSignal`, i.e., change to a running state. A running realtime signal is a source of activation when in a scoped memory and is a member of the root set when in the heap. A running realtime signal can be triggered.

[See Section stop\(\)](#)

Parameters

`disabled` true for starting in a disabled state.

Throws

`IllegalStateException` when this `POSIXRealtimeSignal` has already been started.

Signature

```
public final
boolean stop()
throws IllegalStateException
```

Stop this `POSIXRealtimeSignal`. A stopped realtime signal ceases to be a source of activation and no longer cause any AE attached to it to be a source of activation.

Throws

`IllegalStateException` when this `POSIXRealtimeSignal` is not running.

Returns

`true` when this was *enabled* and `false` otherwise.

send(long, long)*Signature*

```
public native
boolean send(long pid,
             long payload)
```

Send this signal to another process

Parameters

`pid` of the process to which to send the signal

Returns

`true` when signal can be sent, otherwise `false`.

13.3.1.3 POSIXRealtimeSignalDispatcher

Inheritance

```
java.lang.Object
  javax.realtime.ActiveEventDispatcher
    javax.realtime.POSIXRealtimeSignalDispatcher
```

Provides a means of dispatching a set of `POSIXRealtimeSignal`⁴s. An application can provide its own dispatcher, providing the priority for the internal dispatching thread. This dispatching thread calls `process()` each time the signal is triggered.

⁴Section 13.3.1.2

13.3.1.3.1 Constructors

POSIXRealtimeSignalDispatcher(SchedulingParameters)

Signature

```
public  
    POSIXRealtimeSignalDispatcher(SchedulingParameters schedule)
```

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`schedule` give the parameters for scheduling this dispatcher

13.3.1.3.2 Methods

register(POSIXRealtimeSignal)

Signature

```
public  
    void register(POSIXRealtimeSignal signal)  
    throws RegistrationException,  
           IllegalStateException,  
           IllegalArgumentException
```

Register `signal` with this dispatcher.

Parameters

`signal` to register

Throws

`RegistrationException` when `signal` is already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `signal` is not stopped.

unregister(POSIXRealtimeSignal)

Signature

```
public
void unregister(POSIXRealtimeSignal signal)
throws DeregistrationException,
       IllegalStateException,
       IllegalArgumentException
```

Deregister the `signal` from this dispatcher.

Parameters

`signal` to unregister

Throws

`DeregistrationException` when `signal` is not already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `signal` is not stopped.

destroy*Signature*

```
public
void destroy()
throws IllegalStateException
```

Release all resources thereby making the dispatcher unusable.

Throws

`IllegalStateException` when called on a dispatcher that has one or more registered `POSIXRealtimeSignal`⁵ objects.

13.3.1.4 POSIXSignal

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncEvent
      javax.realtime.POSIXSignal
```

Interfaces

`ActiveEvent`

A `ActiveEvent`⁶ subclass for defining a POSIX signal.

⁵Section 13.3.1.2

⁶Section 8.4.1.1

13.3.1.4.1 Fields

MAX_NUM_SIGNALS

```
public static final MAX_NUM_SIGNALS
this number of signals can be processed.
```

13.3.1.4.2 Methods

isPOSIXSignal(String)

Signature

```
public static
boolean isPOSIXSignal(String name)
```

Determine if a signal with a given name is registered.

Parameters

name of the signal

Returns

true when a signal with the given name is registered

getId(String)

Signature

```
public static
int getId(String name)
```

Get the ID of a registered signal.

Parameters

name of the signal for which to search

Returns

the ID of the signal named by **name**

get(String)

Signature

```
public static  
    javax.realtime.POSIXSignal get(String name)
```

Get the registered signal with the given name.

Parameters

name of the signal to get.

Returns

the registered signal with name or `null`.

get(int)

Signature

```
public static  
    javax.realtime.POSIXSignal get(int id)
```

Get the signal corresponding to a given id.

Parameters

id of a registered signal

Returns

the signal corresponding to id or `null`.

getProcessId

Signature

```
public static  
    long getProcessId()
```

Obtain the OS Id of the JVM process. When running in kernel space, the result is VM dependent and must be documented. This number returned is only usable with `POSIXSignal.send(long)`⁷.

Returns

the OS process id.

⁷Section [13.3.1.4.2](#)

getId

Signature

```
public  
int getId()
```

Get the number of this signal.

Returns

the signal number

getName

Signature

```
public  
java.lang.String getName()
```

Get the name of this signal.

Returns

the name of this signal.

getDispatcher

Signature

```
public  
jvax.realtime.POSIXSignalDispatcher getDispatcher()
```

isActive

Signature

```
public  
boolean isActive()
```

Determine the activation state of this signal, i.e., it has been started.

Returns

`true` when active, `false` otherwise.

isRunning

Signature

```
public  
boolean isRunning()
```

Determine the firing state (releasing or skipping) of this signal, i.e., it is active and enabled.

Returns

true when releasing, **false** when skipping.

start

Signature

```
public  
void start()  
throws IllegalStateException
```

Start this POSIXSignal, i.e., change to a running state. A running signal is a source of activation when in a scoped memory and is a member of the root set when in the heap. A running signal can be triggered.

[See Section stop\(\)](#)

Throws

IllegalStateException when this POSIXSignal has already been started.

start(boolean)

Signature

```
public  
void start(boolean disabled)  
throws IllegalStateException
```

Start this POSIXSignal, i.e., change to a running state. A running signal is a source of activation when in a scoped memory and is a member of the root set when in the heap. A running signal can be triggered.

[See Section stop\(\)](#)

Parameters

disabled true for starting in a disabled state.

Throws

`IllegalStateException` when this `POSIXSignal` has already been started.

stop*Signature*

```
public
boolean stop()
throws IllegalStateException
```

Stop this `POSIXSignal`. A stopped signal ceases to be a source of activation and no longer cause any AE attached to it to be a source of activation.

Throws

`IllegalStateException` when this `POSIXSignal` is not running.

Returns

`true` when this was *enabled* and `false` otherwise.

send(long)*Signature*

```
public
void send(long pid)
throws POSIXInvalidSignalException,
        POSIXSignalPermissionException,
        POSIXInvalidTargetException
```

Send this signal to another process or process group.

On POSIX systems running in user space, the following holds:

- when `pid` is positive, the signal is sent to `pid`;
- when `pid` equals 0, the signal is sent to every process in the process group of the current process;
- when `pid` equals -1, the signal is sent to every process for which the calling process has permission to send signals, except for possibly OS-defined system processes; otherwise
- when `pid` is less than -1, the signal is sent to every process in the process group -`pid`.

POSIX.1-2001 requires the underlying mechanism of `signal.send(-1)` to send `signal` to all processes for which the current process may signal, except possibly for some OS-defined system processes.

For an RTVM running in kernel space, the meaning of the `pid` is implementation dependent, though it should be as closed to the standard definition as possible.

Parameters

`pid` Id of the process to which to send the signal

Throws

`POSIXInvalidSignalException` when the signal number is not valid.

`POSIXSignalPermissionException` when the process does not have permission to send the target.

`POSIXInvalidTargetException` when the target does not exist.

13.3.1.5 POSIXSignalDispatcher

Inheritance

```
java.lang.Object
  javax.realtime.ActiveEventDispatcher
  javax.realtime.POSIXSignalDispatcher
```

Provides a means of dispatching a set of `POSIXSignal`⁸s. An application can provide its own dispatcher, providing the priority for the internal dispatching thread. This dispatching thread calls `process()` each time the signal is triggered.

13.3.1.5.1 Constructors

POSIXSignalDispatcher(SchedulingParameters)

Signature

```
public
POSIXSignalDispatcher(SchedulingParameters scheduling)
```

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`scheduling` give the parameters for scheduling this dispatcher

⁸Section 13.3.1.4

13.3.1.5.2 Methods

register(POSIXSignal)

Signature

```
public synchronized
void register(POSIXSignal signal)
throws RegistrationException,
        IllegalStateException,
        IllegalArgumentException
```

Register a POSIX signal with this dispatcher.

Parameters

signal to register

Throws

RegistrationException when signal is already registered.
IllegalStateException when this object has been destroyed.
IllegalArgumentException when signal is not stopped.

unregister(POSIXSignal)

Signature

```
public synchronized
void unregister(POSIXSignal signal)
throws DeregistrationException,
        IllegalStateException,
        IllegalArgumentException
```

Deregister a POSIX Signal form this dispatcher. (This is a really naive implementation.)

Parameters

signal to deregister

Throws

DeregistrationException when signal not is already registered.
IllegalStateException when this object has been destroyed.
IllegalArgumentException when signal is not stopped.

destroy

Signature

```
public  
void destroy()  
throws IllegalStateException
```

Release all reasources thereby making the dispatcher unusable.

Throws

`IllegalStateException` when called on a dispatcher that has one or more registered `POSIXSignal`⁹ objects.

13.3.1.6 RealtimeSecurity

Inheritance

```
java.lang.Object  
  javax.realtime.RealtimeSecurity
```

Security policy object for realtime specific issues. Primarily used to control access to physical memory.

Security requirements are generally application-specific. Every implementation shall have a default `RealtimeSecurity` instance, and a way to install a replacement at run-time, `RealtimeSystem.setSecurityManager`¹⁰. The default security is minimal. All security managers should prevent access to JVM internal data and the Java heap; additional protection is implementation-specific and must be documented.

13.3.1.6.1 Constructors

RealtimeSecurity

Signature

```
public  
RealtimeSecurity()
```

⁹Section [13.3.1.4](#)

¹⁰Section [13.3.1.7.2](#)

Create an `RealtimeSecurity` object.

13.3.1.6.2 Methods

checkAccessPhysical

Signature

```
public
void checkAccessPhysical()
throws SecurityException
```

Check whether the application is allowed to access physical memory.

Throws

SecurityException The application doesn't have permission to access physical memory.

checkAccessPhysicalRange(long, long)

Signature

```
public
void checkAccessPhysicalRange(long base,
                               long size)
throws SecurityException
```

Checks whether the application is allowed to access physical memory within the specified range.

Parameters

base The beginning of the address range.

size The size of the address range.

Throws

SecurityException The application doesn't have permission to access the memory in the given range.

checkSetFilter

Signature

```
public
void checkSetFilter()
throws SecurityException
```

Checks whether the application is allowed to register [PhysicalMemoryTypeFilter](#)¹¹ objects with the [PhysicalMemoryManager](#)¹².

Throws

SecurityException The application doesn't have permission to register filter objects.

checkSetMonitorControl(MonitorControl)

Signature

```
public
void checkSetMonitorControl(MonitorControl policy)
throws SecurityException
```

Checks whether the application is allowed to set the default monitor control policy.

Parameters

policy The new policy

Throws

SecurityException when the application doesn't have permission to change the default monitor control policy to **policy**.

checkAEHSetDaemon

Signature

```
public
void checkAEHSetDaemon()
throws SecurityException
```

Checks whether the application is allowed to set the daemon status of an AEH.

Throws

SecurityException when the application is not permitted to alter the daemon status.

¹¹Section [15.3.1.1](#)

¹²Section [15.3.3.6](#)

checkSetScheduler

Signature

```
public  
void checkSetScheduler()  
throws SecurityException
```

Checks whether the application is allowed to set the scheduler.

Throws

`SecurityException` The application doesn't have permission to set the scheduler.

checkCreateRealtimeThread

Signature

```
public  
void checkCreateRealtimeThread()  
throws SecurityException
```

Check if an application may create a realtime thread.

Throws

`SecurityException` when not allowed

checkCreateTimer

Signature

```
public  
void checkCreateTimer()  
throws SecurityException
```

Check if an application may create a Timer.

Throws

`SecurityException` when not allowed.

checkPOSIXSendSignal(POSIXSignal, long)

Signature

```
public  
void checkPOSIXSendSignal(POSIXSignal signal,
```

long pid)

throws `SecurityException`

Check if the given signal can be sent to the given process id.

Parameters

`signal` is the signal being sent

`pid` is the id to which the signal is being set.

Throws

`SecurityException` when the operation is not allowed.

13.3.1.7 RealtimeSystem

Inheritance

java.lang.Object

[javax.realtime.RealtimeSystem](#)

`RealtimeSystem` provides a means for tuning the behavior of the implementation by specifying parameters such as the maximum number of locks that can be in use concurrently, and the monitor control policy. In addition, `RealtimeSystem` provides a mechanism for obtaining access to the security manager, garbage collector, and scheduler, to query or set parameters.

13.3.1.7.1 Fields

BIG_ENDIAN

public static final BIG_ENDIAN

Value indicating that the highest order byte of a bit word is stored at the lowest byte address: the int 0x0A0B0C0D is stored in the byte sequence 0x0A, 0x0B, 0x0C, 0x0D. and the long 0x0102030405060708 is stored in the sequence 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08.

LITTLE_ENDIAN

public static final LITTLE_ENDIAN

Value indicating that the lowest order byte of a word is stored at the lowest byte address: the int 0x0A0B0C0D is stored in the byte sequence 0x0D, 0x0C, 0x0B,

0x0A and the long 0x0102030405060708 is stored in the sequence 0x08, 0x07, 0x06, 0x05, 0x04, 0x03, 0x02, 0x01.

PDP_ENDIAN

```
public static final PDP_ENDIAN
```

Value indicating a mixed endian mode used by among others the PDP-11: the int 0x0A0B0C0D is stored in the byte sequence 0x0B, 0x0A, 0x0D, 0x0C, and the long 0x0102030405060708 is stored in the sequence 0x03, 0x04, 0x01, 0x02, 0x07, 0x08, 0x05, 0x06.

BYTE_ORDER

```
public static final BYTE_ORDER
```

The byte ordering of the underlying hardware.

13.3.1.7.2 Methods

currentGC

Signature

```
public static  
javax.realtime.GarbageCollector currentGC()
```

Return a reference to the currently active garbage collector for the heap.

Returns

A [GarbageCollector](#)¹³ object which is the current collector collecting objects on the conventional Java heap.

getConcurrentLocksUsed

Signature

```
public static  
int getConcurrentLocksUsed()
```

¹³Section [13.3.1.1](#)

Gets the maximum number of locks that have been used concurrently. This value can be used for tuning the concurrent locks parameter, which is used as a hint by systems that use a monitor cache.

Returns

An integer whose value is the maximum number of locks that have been used concurrently. When the number of concurrent locks is not tracked by the implementation, return -1. Note that when the number of concurrent locks is not tracked, the number of available concurrent locks is effectively unlimited.

getMaximumConcurrentLocks

Signature

```
public static  
int getMaximumConcurrentLocks()
```

Gets the maximum number of locks that can be used concurrently without incurring an execution time increase as set by the `setMaximumConcurrentLocks()` methods.

Note: Any relationship between this method and `setMaximumConcurrentLocks` is implementation-specific. This method returns the actual maximum number of concurrent locks the platform can currently support, or `Integer.MAX_VALUE` when there is no maximum. The `setMaximumConcurrentLocks` method give the implementation a hint as to the maximum number of concurrent locks it should expect.

Returns

An integer whose value is the maximum number of locks that can be in simultaneous use.

getSecurityManager

Signature

```
public static  
javafx.realtime.RealtimeSecurity getSecurityManager()
```

Gets a reference to the security manager used to control access to realtime system features such as access to physical memory.

Returns

A **RealtimeSecurity**¹⁴ object representing the default realtime security manager.

¹⁴Section 13.3.1.6

setMaximumConcurrentLocks(int)

Signature

```
public static  
void setMaximumConcurrentLocks(int numLocks)
```

Sets the anticipated maximum number of locks that may be held or waited on concurrently. Provide a hint to systems that use a monitor cache as to how much space to dedicate to the cache.

Parameters

numLocks An integer whose value becomes the number of locks that can be in simultaneous use without incurring an execution time increase. When **number** is less than or equal to zero nothing happens. When the system does not use this hint this method has no effect other than on the value returned by [getMaximumConcurrentLocks\(\)](#)¹⁵.

setMaximumConcurrentLocks(int, boolean)

Signature

```
public static  
void setMaximumConcurrentLocks(int number,  
                                boolean hard)
```

Sets the anticipated maximum number of locks that may be held or waited on concurrently. Provide a limit for the size of the monitor cache on systems that provide one when **hard** is true.

Parameters

number The maximum number of locks that can be in simultaneous use without incurring an execution time increase. When **number** is less than or equal to zero nothing happens. When the system does not use this hint this method has no effect other than on the value returned by [getMaximumConcurrentLocks\(\)](#)¹⁶.
hard When true, **number** sets a limit. When a lock is attempted which would cause the number of locks to exceed **number** then a [ResourceLimitError](#)¹⁷ is thrown. When the system does not limit use of concurrent locks, this parameter is silently ignored.

¹⁵Section [13.3.1.7.2](#)

¹⁶Section [13.3.1.7.2](#)

¹⁷Section [14.3.3.5](#)

setSecurityManager(RealtimeSecurity)

Signature

```
public static  
void setSecurityManager(RealtimeSecurity manager)
```

Sets a new realtime security manager.

Parameters

manager A [RealtimeSecurity](#)¹⁸ object which will become the new security manager.

Throws

`SecurityException` when security manager has already been set.

getInitialMonitorControl

Signature

```
public static  
javax.realtime.MonitorControl getInitialMonitorControl()
```

Returns the monitor control object that represents the initial monitor control policy.

Returns

The initial monitor control policy.

supports(RTSJModule)

Signature

```
public static  
boolean supports(RTSJModule module)
```

Determine if a particular module is supported.

Parameters

module of interest.

Returns

`true` when module is supported; otherwise `false`.

¹⁸Section [13.3.1.6](#)

13.4 Rationale

This specification accommodates the variation in underlying systems in a number of ways. The `RealtimeSystem` class functions in similar capacity to `java.lang.System`. Similarly, the `RealtimeSecurity` class functions similarly to `java.lang.SecurityManager`. The concept of optionally required classes provides additional flexibility. Such classes provide a commonality that can be relied upon by program logic that intends to execute on implementations that supports a given function, such as `POSIXSignal` and `POSIXRealtimeSignal` encapsulate common functionality for POSIX compliant systems.

Chapter 14

Exceptions

14.1 Overview

As with other Java specifications, the RTSJ uses exceptions and errors to signal conditions that are abnormal, incorrect, or disallowed. In cases where these exceptional and error conditions are substantially the same as those defined in conventional Java, those exceptions and errors are used. They are taken primarily from the `java.lang` package, but also a few from the `java.lang.reflect` and `java.io` packages as well. In other cases, new exceptions are defined in the `javax.realtime` package. These exception classes provide

- additional exception classes required for other sections of this specification,
- the ability to throw exceptions that do not allocate memory, and
- the ability to asynchronously transfer the control of program logic (see `AsynchronouslyInterruptedException`).

14.2 Semantics

This list establishes the semantics that are applicable across the classes of this section. Semantics that apply to particular classes, constructors, methods, and fields will be found in the class description and the constructor, method, and field detail sections.

- All classes in this section are required.
- All exceptions, except `AsynchronouslyInterruptedException`, are required to have semantics exactly as those of their eventual superclass in the `java.*` hierarchy.

Though the `AsynchronouslyInterruptedException` class defines an exception, it provides additional functionality for supporting ATC. This functionality is more closely related to asynchronous operation than to exception handling. For this

reason, it is not included in this chapter, but rather in Chapter 8 on asynchrony.

14.3 Package javax.realtime

14.3.1 Interfaces

14.3.1.1 StaticThrowable

A marker class to indicate that a `Throwable` is intended to be created once and reused. `Throwables` that implement this interface kept their state in a `RealtimeThread` local data structure instead of the object itself. This means that data is only valid until the next `StaticThrowable` is thrown in the context of the current thread. Instances `AsyncBaseEventHandler`¹ always have some instance of `RealtimeThread` when executing. Having a marker interface makes it easier to provide checking tools to ensure the proper throw sequence for all `Throwables` thrown from application code.

See [Section ConfigurationParameters](#)

14.3.1.1.1 Methods

`initMessage(String)`

Signature

```
public  
void initMessage(String message)
```

Set the message in SO local storage. This is the only method that is not also defined in `Throwable`.

Parameters

`message` is the text to save.

`getMessage`

Signature

```
public  
java.lang.String getMessage()
```

¹Section [8.4.3.3](#)

get the message describing the problem from SO local memory.

Returns

the message given to the constructor or `null` when no message was set.

getLocalizedMessage

Signature

```
public  
java.lang.String getLocalizedMessage()
```

Subclasses may override this message to get an error message that is localized to the default locale.

By default it returns `getMessage()`.

Returns

the value of `getMessage()`.

initCause(Throwable)

Signature

```
public  
java.lang.Throwable initCause(Throwable causingThrowable)
```

Initializes the cause to the given Throwable in SO local memory.

Parameters

`causingThrowable` the reason why this Throwable gets Thrown.

Throws

`IllegalArgumentException` when the cause is this Throwable itself.

Returns

the reference to this Throwable.

getCause

Signature

```
public  
java.lang.Throwable getCause()
```

`getCause` returns the cause of this exception or `null` when no cause was set. The cause is another exception that was caught before this exception was created.

Returns

The cause or `null`.

fillInStackTrace

Signature

```
public  
java.lang.Throwable fillInStackTrace()
```

Calls into the virtual machine to capture the current stack trace in SO local memory.

Returns

a reference to this `Throwable`.

setStackTrace(StackTraceElement)

Signature

```
public  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)  
throws NullPointerException
```

This method allows overriding the stack trace that was filled during construction of this object. It is intended to be used in a serialization context when the stack trace of a remote exception should be treated like a local.

Parameters

`new_stackTrace` the stack trace to replace be used.

Throws

`NullPointerException` when `new_stackTrace` or any element of `new_stackTrace` is `null`.

getStackTrace

Signature

```
public  
java.lang.StackTraceElement[] getStackTrace()
```

Get the stack trace created by `fillInStackTrace` for this `Throwable` as an array of `StackTraceElements`.

The stack trace does not need to contain entries for all methods that are actually on the call stack, the virtual machine may decide to skip some stack trace entries. Even an empty array is a valid result of this function.

Repeated calls of this function without intervening calls to `fillInStackTrace` will return the same result.

For JamaicaVM, the stack trace may omit methods that are compiled by the static compiler. Particularly, methods are compiled and that do not contain an exception handler themselves usually do not require the creation of a stack frame at runtime. To improve performance, no stack frame is generated in these cases.

When memory areas of the RTSJ are used (see [MemoryArea²](#)), and this Throwable was allocated in a different memory area than the current allocation context, the resulting stack trace will be allocated in either the same memory area this was allocated in or the current memory area, depending on which is the least deeply nested, thereby creating objects that are assignment compatible with both areas.

Returns

array representing the stack trace, never `null`.

printStackTrace

Signature

```
public  
void printStackTrace()
```

Print stack trace of this Throwable to `System.err`.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

printStackTrace(PrintStream)

Signature

```
public  
void printStackTrace(PrintStream stream)
```

Print the stack trace of this Throwable to the given stream.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

²Section [11.4.2.3](#)

For JamaicaVM, when printing to the stream causes another exception, low-level exception printing mechanisms provided by class `com.aicas.jamaica.lang.Debug` will be used to print the exception to `stderr`.

Parameters

`stream` the stream to print to.

printStackTrace(PrintWriter)

Signature

```
public  
void printStackTrace(PrintWriter s)
```

Print the stack trace of this Throwable to the given `PrintWriter`.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

For JamaicaVM, when printing to the `PrintWriter` causes another exception, low-level exception printing mechanisms provided by class `com.aicas.jamaica.lang.Debug` will be used to print the exception to `stderr`.

Parameters

`s` the `PrintWriter` to write to.

14.3.2 Exceptions

14.3.2.1 ArrivalTimeQueueOverflowException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javax.realtime.ArrivalTimeQueueOverflowException
```

When an arrival time occurs and should be queued but the queue already holds a number of times equal to the initial queue length defined by this an instance of this class may be thrown. When the arrival time is a result of a happening to which the instance of `AsyncEventHandler` is bound then the arrival time is ignored.

14.3.2.1.1 Constructors

ArrivalTimeQueueOverflowException

Signature

```
public  
ArrivalTimeQueueOverflowException()
```

A constructor for `ArrivalTimeQueueOverflowException`.

ArrivalTimeQueueOverflowException(String)

Signature

```
public  
ArrivalTimeQueueOverflowException(String description)
```

A descriptive constructor for `ArrivalTimeQueueOverflowException`.

Parameters

description A description of the exception.

14.3.2.2 CeilingViolationException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        java.lang.IllegalArgumentException  
          java.lang.IllegalThreadStateException  
            javax.realtime.CeilingViolationException
```

This exception is thrown when a schedulable or `java.lang.Thread` attempts to lock an object governed by an instance of `PriorityCeilingEmulation`³ and the thread or SO's base priority exceeds the policy's ceiling.

³Section 7.4.1.2

14.3.2.2.1 Methods

getCeiling

Signature

```
public  
int getCeiling()
```

Gets the ceiling of the `PriorityCeilingEmulation` policy which was exceeded by the base priority of an SO or thread that attempted to synchronize on an object governed by the policy, which resulted in throwing of `this`.

Returns

The ceiling of the `PriorityCeilingEmulation` policy which caused this exception to be thrown.

getCallerPriority

Signature

```
public  
int getCallerPriority()
```

Gets the base priority of the SO or thread whose attempt to synchronize resulted in the throwing of `this`.

Returns

The synchronizing thread's base priority.

14.3.2.3 DeregistrationException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javax.realtime.DeregistrationException
```

An exception to throw when trying to deregister an [ActiveEvent](#)⁴ from an [ActiveEventDispatcher](#)⁵ to which it is not registered.

14.3.2.3.1 Constructors

DeregistrationException

Signature

```
public  
DeregistrationException()
```

Create an exception with neither message nor cause

DeregistrationException(String)

Signature

```
public  
DeregistrationException(String message)
```

Create an exception with just a message.

Parameters

message a description of the reason for this exception

DeregistrationException(Throwable)

Signature

```
public  
DeregistrationException(Throwable cause)
```

Create an exception with just a cause.

Parameters

cause another exception that caused to this one.

⁴Section [8.4.1.1](#)

⁵Section [8.4.3.1](#)

DeregistrationException(String, Throwable)

Signature

```
public  
DeregistrationException(String message,  
                          Throwable cause)
```

Create an exception with a message and a cause.

Parameters

message a description of the reason for this exception
cause another exception that caused to this one.

14.3.2.4 InaccessibleAreaException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javax.realtime.InaccessibleAreaException
```

The specified memory area is not on the current thread's scope stack.

14.3.2.4.1 Constructors

InaccessibleAreaException

Signature

```
public  
InaccessibleAreaException()
```

A constructor for InaccessibleAreaException.

InaccessibleAreaException(String)

Signature

```
public  
InaccessibleAreaException(String description)
```

A descriptive constructor for `InaccessibleAreaException`.

Parameters

`description` Description of the error.

14.3.2.5 LateStartException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      javax.realtime.LateStartException
```

Exception thrown when a periodic realtime thread or timer is started after its assigned, absolute, start time.

14.3.2.5.1 Constructors

LateStartException

Signature

```
public  
LateStartException()
```

LateStartException(String)

Signature

```
public  
LateStartException(String description)
```

14.3.2.6 MITViolationException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.MITViolationException
```

Thrown by the `AsyncEvent.fire()`⁶ on a minimum interarrival time violation. More specifically, it is thrown under the semantics of the base priority scheduler's sporadic parameters' `mitViolationExcept` policy when an attempt is made to introduce a release that would violate the MIT constraint.

14.3.2.6.1 Constructors

MITViolationException

Signature

```
public
MITViolationException()
```

A constructor for `MITViolationException`.

MITViolationException(String)

Signature

```
public
MITViolationException(String description)
```

A descriptive constructor for `MITViolationException`.

Parameters

description Description of the error.

⁶Section [8.4.3.4.2](#)

14.3.2.7 MemoryInUseException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.MemoryInUseException
```

There has been attempt to allocate a range of physical or virtual memory that is already in use.

14.3.2.7.1 Constructors

MemoryInUseException

Signature

```
public
MemoryInUseException()
```

A constructor for MemoryInUseException.

MemoryInUseException(String)

Signature

```
public
MemoryInUseException(String description)
```

A descriptive constructor for MemoryInUseException.

Parameters

description Description of the error.

14.3.2.8 MemoryScopeException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.MemoryScopeException
```

when construction of any of the wait-free queues is attempted with the ends of the queue in incompatible memory areas. Also thrown by wait-free queue methods when such an incompatibility is detected after the queue is constructed.

14.3.2.8.1 Constructors

MemoryScopeException*Signature*

```
public
MemoryScopeException()
```

A constructor for MemoryScopeException.

MemoryScopeException(String)*Signature*

```
public
MemoryScopeException(String description)
```

A descriptive constructor for MemoryScopeException.

Parameters

description A description of the exception.

14.3.2.9 MemoryTypeConflictException

Inheritance

```
java.lang.Object
  java.lang.Throwable
```

```
java.lang.Exception
  java.lang.RuntimeException
    javax.realtime.MemoryTypeConflictException
```

This exception is thrown when the [PhysicalMemoryManager](#)⁷ is given conflicting specifications for memory. The conflict can be between types in an array of memory type specifiers, or between the specifiers and a specified base address.

14.3.2.9.1 Constructors

MemoryTypeConflictException

Signature

```
public
MemoryTypeConflictException()
```

A constructor for MemoryTypeConflictException.

MemoryTypeConflictException(String)

Signature

```
public
MemoryTypeConflictException(String description)
```

A descriptive constructor for MemoryTypeConflictException.

Parameters

description A description of the exception.

14.3.2.10 OffsetOutOfBoundsException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
```

⁷Section [15.3.3.6](#)


```
java.lang.RuntimeException  
    javax.realtime.OffsetOutOfBoundsException
```

when the constructor of an [ImmutablePhysicalMemory](#)⁸, [LTPhysicalMemory](#)⁹, [VT-PhysicalMemory](#)¹⁰, [RawMemoryAccess](#)¹¹, or [RawMemoryFloatAccess](#)¹² is given an invalid address.

14.3.2.10.1 Constructors

OffsetOutOfBoundsException

Signature

```
public  
    OffsetOutOfBoundsException()
```

A constructor for `OffsetOutOfBoundsException`.

OffsetOutOfBoundsException(String)

Signature

```
public  
    OffsetOutOfBoundsException(String description)
```

A descriptive constructor for `OffsetOutOfBoundsException`.

Parameters

description A description of the exception.

14.3.2.11 ProcessorAffinityException

Inheritance

⁸Section [15.3.3.1](#)

⁹Section [15.3.3.3](#)

¹⁰Section [15.3.3.13](#)

¹¹Section [15.3.3.9](#)

¹²Section [15.3.3.10](#)

java.lang.Object
 java.lang.Throwable
 java.lang.Exception
 [javax.realtime.ProcessorAffinityException](#)

Exception used to report processor affinity-related errors.

14.3.2.11.1 Constructors

ProcessorAffinityException

Signature

```
public  
ProcessorAffinityException()
```

ProcessorAffinityException(String)

Signature

```
public  
ProcessorAffinityException(String msg)
```

14.3.2.12 RegistrationException

Inheritance

java.lang.Object
 java.lang.Throwable
 java.lang.Exception
 java.lang.RuntimeException
 [javax.realtime.RegistrationException](#)

An exception to throw when trying to register an [ActiveEvent](#)¹³ with an [ActiveEvent-Dispatcher](#)¹⁴ to which it is already registered.

¹³Section [8.4.1.1](#)

¹⁴Section [8.4.3.1](#)

14.3.2.12.1 Constructors

RegistrationException

Signature

```
public  
RegistrationException()
```

Create an exception with neither message nor cause

RegistrationException(String)

Signature

```
public  
RegistrationException(String message)
```

Create an exception with just a message.

Parameters

message a description of the reason for this exception

RegistrationException(Throwable)

Signature

```
public  
RegistrationException(Throwable cause)
```

Create an exception with just a cause.

Parameters

cause another exception that caused to this one.

RegistrationException(String, Throwable)

Signature

```
public
RegistrationException(String message,
                      Throwable cause)
```

Create an exception with a message and a cause.

Parameters

message a description of the reason for this exception
cause another exception that caused to this one.

14.3.2.13 ScopedCycleException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.ScopedCycleException
```

Thrown when a schedulable attempts to enter an instance of [ScopedMemory](#)¹⁵ where that operation would cause a violation of the single parent rule.

14.3.2.13.1 Constructors

ScopedCycleException

Signature

```
public
ScopedCycleException()
```

A constructor for ScopedCycleException.

ScopedCycleException(String)

Signature

¹⁵Section [15.3.3.11](#)

```
public
    ScopedCycleException(String description)
```

A descriptive constructor for `ScopedCycleException`.

Parameters

`description` Description of the error.

14.3.2.14 SizeOutOfBoundsException

Inheritance

```
java.lang.Object
    java.lang.Throwable
        java.lang.Exception
            java.lang.RuntimeException
                javax.realtime.SizeOutOfBoundsException
```

To throw when the constructor of an `ImmutablePhysicalMemory`¹⁶, `LTPPhysicalMemory`¹⁷, or `VTPPhysicalMemory`¹⁸ is given an invalid size or when a memory access generated by a raw memory accessor instance (See `RawMemory`¹⁹.) would cause access to an invalid address.

14.3.2.14.1 Constructors

SizeOutOfBoundsException

Signature

```
public
    SizeOutOfBoundsException()
```

A constructor for `SizeOutOfBoundsException`.

¹⁶Section 15.3.3.1

¹⁷Section 15.3.3.3

¹⁸Section 15.3.3.13

¹⁹Section 12.4.1.16

SizeOutOfBoundsException(String)

Signature

```
public
SizeOutOfBoundsException(String description)
```

A descriptive constructor for `SizeOutOfBoundsException`.

Parameters

`description` The description of the exception.

14.3.2.15 UnknownHappeningException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.UnknownHappeningException
```

This exception is used to indicate a situation where an instance of `AsyncEvent`²⁰ attempts to bind to a happening that does not exist.

14.3.2.15.1 Constructors

UnknownHappeningException

Signature

```
public
UnknownHappeningException()
```

A constructor for `UnknownHappeningException`.

²⁰Section 8.4.3.4

UnknownHappeningException(String)

Signature

```
public  
UnknownHappeningException(String description)
```

A descriptive constructor for UnknownHappeningException.

Parameters

`description` Description of the error.

14.3.2.16 UnsupportedPhysicalMemoryException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javax.realtime.UnsupportedPhysicalMemoryException
```

Thrown when the underlying hardware does not support the type of physical memory requested.

[See Section PhysicalMemoryFactory](#)

14.3.2.16.1 Constructors

UnsupportedPhysicalMemoryException

Signature

```
public  
UnsupportedPhysicalMemoryException()
```

A constructor for UnsupportedPhysicalMemoryException.

UnsupportedPhysicalMemoryException(String)

Signature

```
public  
UnsupportedPhysicalMemoryException(String description)
```

A descriptive constructor for `UnsupportedPhysicalMemoryException`.

Parameters

description The description of the exception.

14.3.2.17 UnsupportedRawMemoryRegionException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javax.realtime.UnsupportedRawMemoryRegionException
```

14.3.2.17.1 Constructors

UnsupportedRawMemoryRegionException

Signature

```
public  
UnsupportedRawMemoryRegionException()
```

UnsupportedRawMemoryRegionException(String)

Signature

```
public  
UnsupportedRawMemoryRegionException(String s)
```


UnsupportedRawMemoryRegionException(Throwable)

Signature

```
public  
UnsupportedRawMemoryRegionException(Throwable ex)
```

UnsupportedRawMemoryRegionException(String, Throwable)

Signature

```
public  
UnsupportedRawMemoryRegionException(String s,  
                                     Throwable ex)
```

14.3.3 Classes

14.3.3.1 AlignmentError

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Error  
      javafx.runtime.AlignmentError
```

The exception thrown on an on a request for a raw memory factory to return memory for a base address that is aligned such that the factory cannot guarantee that loads and stores based on that address will meet the factory's specifications. For instance, on many processors, odd addresses are unsuitable for anything but byte access.

14.3.3.1.1 Constructors

AlignmentError

Signature

```
public  
AlignmentError()
```

14.3.3.2 BacktraceManagement

Inheritance

```
java.lang.Object  
  javax.realtime.BacktraceManagement
```

Provide the static methods for managing the thread local memory used for storing the data needed by preallocated exceptions. Preallocated methods can implement their methods using these methods. User code should not call these methods directly.

14.3.3.2.1 Constructors

BacktraceManagement

Signature

```
public  
BacktraceManagement()
```

14.3.3.2.2 Methods

fillInStackTrace

Signature

```
public static  
void fillInStackTrace()
```

Capture the current thread's stack trace and save it in thread local storage. Only the part of the stack trace that fits in the preallocated buffer is stored. This method

should be called by a preallocated exception to implement its method of the same name.

getMessage

Signature

```
public static  
java.lang.String getMessage()
```

Get the message from thread local storage that was saved by the last preallocated exception thrown. This method should be called by a preallocated exception to implement its method of the same name.

Returns

the message

initMessage(String)

Signature

```
public static  
void initMessage(String message)
```

Save the message in thread local storage for later retrieval. Only the part of the message that fits in the preallocated buffer is stored. This method should be called by a preallocated exception to implement its method of the same name.

Parameters

message the message to save.

getCause

Signature

```
public static  
java.lang.Throwable getCause()
```

Get the cause from thread local storage that was saved by the last preallocated exception thrown. The actual exception that of the cause is not saved, but just a reference to its type. This returns a newly allocated exception without any valid content, i.e., no valid stack trace. This method should be called by a preallocated exception to implement its method of the same name.

Returns

the message

initCause(Throwable)

Signature

```
public static  
void initCause(Throwable causingThrowable)
```

Save the message in thread local storage for later retrieval. Only a reference to the exception class is stored. The rest of its information is lost. This method should be called by a preallocated exception to implement its method of the same name.

Parameters

causingThrowable

getStackTrace

Signature

```
public static  
java.lang.StackTraceElement[] getStackTrace()
```

Get the stack trace from thread local storage that was saved by the last preallocated exception thrown. This method should be called by a preallocated exception to implement its method of the same name.

Returns

an array of the elements of the stack trace.

getLocalizedMessage

Signature

```
public static  
java.lang.String getLocalizedMessage()
```

setStackTrace(StackTraceElement)

Signature

```
public static  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)
```

printStackTrace

Signature

```
public static  
void printStackTrace()
```

printStackTrace(PrintStream)

Signature

```
public static  
void printStackTrace(PrintStream stream)
```

printStackTrace(PrintWriter)

Signature

```
public static  
void printStackTrace(PrintWriter writer)
```

14.3.3.3 IllegalAssignmentError

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Error  
      javax.realtime.IllegalAssignmentError
```

The exception thrown on an attempt to make an illegal assignment. For example, this will be thrown on any attempt to assign a reference to an object in scoped memory (an area of memory identified by an instance of [ScopedMemory](#)²¹) to a field of an object in immortal memory.

14.3.3.3.1 Constructors

²¹Section [15.3.3.11](#)

IllegalAssignmentError

Signature

```
public  
IllegalAssignmentError()
```

A constructor for `IllegalAssignmentError`.

IllegalAssignmentError(String)

Signature

```
public  
IllegalAssignmentError(String description)
```

A descriptive constructor for `IllegalAssignmentError`.

Parameters

`description` Description of the error.

14.3.3.4 MemoryAccessError

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Error  
      javax.realtime.MemoryAccessError
```

This error is thrown on an attempt to refer to an object in an inaccessible [Memory-Area](#)²². For example this will be when logic in a [NoHeapRealtimeThread](#)²³ attempts to refer to an object in the traditional Java heap.

14.3.3.4.1 Constructors

²²Section [11.4.2.3](#)

²³Section [15.3.3.4](#)

MemoryAccessError

Signature

```
public  
MemoryAccessError()
```

A constructor for `MemoryAccessError`.

MemoryAccessError(String)

Signature

```
public  
MemoryAccessError(String description)
```

A descriptive constructor for `MemoryAccessError`.

Parameters

`description` Description of the error.

14.3.3.5 ResourceLimitError

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Error  
      javax.realtime.ResourceLimitError
```

when an attempt is made to exceed a system resource limit, such as the maximum number of locks.

14.3.3.5.1 Constructors

ResourceLimitError

Signature

```
public  
ResourceLimitError()
```

A constructor for `ResourceLimitError`.

ResourceLimitError(String)

Signature

```
public  
ResourceLimitError(String description)
```

A descriptive constructor for `ResourceLimitError`.

Parameters

description The description of the exception.

14.3.3.6 StaticOutOfMemoryError

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Error  
      java.lang.VirtualMachineError  
        java.lang.OutOfMemoryError  
          javax.realtime.StaticOutOfMemoryError
```

Interfaces

[StaticThrowable](#)

A version of `OutOfMemoryError` that does not require allocation. It should be thrown from all RTSJ memory subclasses except [HeapMemory](#)²⁴. It is up to the implementation as to whether `HeapMemory` throws this exception or its parent.

14.3.3.6.1 Constructors

StaticOutOfMemoryError

²⁴Section [11.4.2.1](#)

Signature

```
public  
StaticOutOfMemoryError()
```

14.3.3.6.2 Methods

get*Signature*

```
public static  
javax.realtime.StaticOutOfMemoryError get()
```

Get the preallocated version of this Throwable. Allocation is done in memory that acts like [ImmutableMemory](#)²⁵. The message and cause are cleared and the stack trace is filled out.

Returns

the preallocated exception

get(String)*Signature*

```
public static  
javax.realtime.StaticOutOfMemoryError get(String message)
```

Same as [get](#)²⁶ except the message is set to `message`

Parameters

`message` text describing the issue.

Returns

the preallocated exception

get(Throwable)*Signature*

²⁵Section [11.4.2.2](#)

²⁶Section [14.3.3.6.2](#)

```
public static
javax.realtime.StaticOutOfMemoryError get(Throwable cause)
```

Same as [get](#)²⁷ except the cause is set to `cause`

Parameters

`cause` a throwable that lead to this issue.

Returns

the preallocated exception

get(String, Throwable)

Signature

```
public static
javax.realtime.StaticOutOfMemoryError get(String Message,
                                           Throwable cause)
```

Same as [get](#)²⁸ except the message is set to `message` and cause is set to `cause`

Parameters

`Message` text describing the issue.

`cause` a throwable that lead to this issue.

Returns

the preallocated exception

initMessage(String)

Signature

```
public
void initMessage(String message)
```

getMessage

Signature

```
public
java.lang.String getMessage()
```

²⁷Section [14.3.3.6.2](#)

²⁸Section [14.3.3.6.2](#)

getLocalizedMessage

Signature

```
public  
java.lang.String getLocalizedMessage()
```

initCause(Throwable)

Signature

```
public  
java.lang.Throwable initCause(Throwable causingThrowable)
```

getCause

Signature

```
public  
java.lang.Throwable getCause()
```

fillInStackTrace

Signature

```
public  
java.lang.Throwable fillInStackTrace()
```

setStackTrace(StackTraceElement)

Signature

```
public  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)  
throws NullPointerException
```

getStackTrace

Signature

```
public  
java.lang.StackTraceElement[] getStackTrace()
```

printStackTrace

Signature

```
public  
void printStackTrace()
```

printStackTrace(PrintStream)

Signature

```
public  
void printStackTrace(PrintStream stream)
```

printStackTrace(PrintWriter)

Signature

```
public  
void printStackTrace(PrintWriter s)
```

14.3.3.7 ThrowBoundaryError

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Error  
      javax.realtime.ThrowBoundaryError
```

Interfaces

```
StaticThrowable
```

The error thrown by `MemoryArea.enter(Runnable logic)`²⁹ when a `Throwable` allocated from memory that is not usable in the surrounding scope tries to propagate out of the scope of the `enter`.

14.3.3.7.1 Constructors

ThrowBoundaryError

Signature

```
public  
ThrowBoundaryError()
```

A constructor for `ThrowBoundaryError`.

ThrowBoundaryError(String)

Signature

```
public  
ThrowBoundaryError(String description)
```

A descriptive constructor for `ThrowBoundaryError`.

Parameters

`description` Description of the error.

14.3.3.7.2 Methods

getPreallocatedThrowable

Signature

```
public  
java.xml.bind.annotation.XmlRootElement getPreallocatedThrowable()
```

²⁹Section [11.4.2.3.2](#)

Get the preallocated instance of this exception.

Returns

the preallocated instance of this exception.

initMessage(String)

Signature

```
public  
void initMessage(String message)
```

14.4 Rationale

The need for additional exceptions given the new semantics added by the other sections of this specification is obvious. That the specification attaches new, nonconventional, exception semantics to **AsynchronouslyInterruptedException** is, perhaps, not so obvious. However, after careful thought, and given our self-imposed directive that only well-defined code blocks would be subject to having their control asynchronously transferred, the chosen mechanism is logical.

Chapter 15

Deprecated Classes

15.1 Overview

Since modules are new in 2.0 and this version introduces new ways of handling happening, POSIX signals, and raw memory access, there is no need to include the old API in the RTSJ subsets. Therefore the deprecated classes have moved here. Only full implementation of the RTSJ should implement them.

15.2 Semantics

Implementations of these classes are optional. They are only needed for backward compatibility. They should not be included in implementations that do not include all modules.

15.3 Package javax.realtime

15.3.1 Interfaces

15.3.1.1 PhysicalMemoryTypeFilter

Implementation or device providers may include classes that implement `PhysicalMemoryTypeFilter` which allow additional characteristics of memory in devices to be specified. Implementations of `PhysicalMemoryTypeFilter` are intended to be used by the [PhysicalMemoryManager](#)¹, not directly from application code.

15.3.1.1.1 Methods

`contains(long, long)`

Signature

```
public
boolean contains(long base,
                 long size)
```

Queries the system about whether the specified range of memory contains any of this type.

See [Section PhysicalMemoryManager.isRemovable](#)

Parameters

base The physical address of the beginning of the memory region.

size The size of the memory region.

Throws

`IllegalArgumentException` when **base** or **size** is negative.

`OffsetOutOfBoundsException` when **base** is less than zero.

`SizeOutOfBoundsException` when **base** plus **size** would be greater than the physical addressing range of the processor.

Returns

true when the specified range contains ANY of this type of memory.

¹Section [15.3.3.6](#)

find(long, long)

Signature

```
public
long find(long base,
          long size)
```

Search for physical memory of the right type.

Parameters

base The physical address at which to start searching.

size The amount of memory to be found.

Throws

`OffsetOutOfBoundsException` when **base** is less than zero.

`SizeOutOfBoundsException` when **base** plus **size** would be greater than the physical addressing range of the processor.

`IllegalArgumentException` when **base** or **size** is negative.

Returns

The address where memory was found or -1 when it was not found.

getVMAttributes

Signature

```
public
int getVMAttributes()
```

Gets the virtual memory attributes of **this**. The value of this field is as defined for the POSIX `mmap` function's `prot` parameter for the platform. The meaning of the bits is platform-dependent. POSIX defines constants for `PROT_READ`, `PROT_WRITE`, `PROT_EXEC`, and `PROT_NONE`.

Returns

The virtual memory attributes as an integer.

getVMFlags

Signature

```
public
int getVMFlags()
```

Gets the virtual memory flags of **this**. The value of this field is as defined for the POSIX `mmap` function's `flags` parameter for the platform. The meaning of the bits is platform-dependent. POSIX defines constants for `MAP_SHARED`, `MAP_PRIVATE`, and `MAP_FIXED`.

Returns

The virtual memory flags as an integer.

initialize(long, long, long)

Signature

```
public
void initialize(long base,
               long vBase,
               long size)
```

When configuration is required for memory to fit the attribute of this object, do the configuration here.

Parameters

base The address of the beginning of the physical memory region.

vBase The address of the beginning of the virtual memory region.

size The size of the memory region.

Throws

`IllegalArgumentException` when **base** or **size** is negative.

`OffsetOutOfBoundsException` when **base** is less than zero.

`SizeOutOfBoundsException` when **base** plus **size** would be greater than the physical addressing range of the processor, or **vBase** plus **size** would exceed the virtual addressing range of the processor.

isPresent(long, long)

Signature

```
public
boolean isPresent(long base,
                 long size)
```

Queries the system about the existence of the specified range of physical memory.

See [Section PhysicalMemoryManager.isRemoved](#)

Parameters

base The address of the beginning of the memory region.

size The size of the memory region.

Throws

IllegalArgumentException when the base and size do not fall into this type of memory.

OffsetOutOfBoundsException when **base** is less than zero.

SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.

Returns

True when all of the memory is present. False when any of the memory has been removed.

isRemovable

Signature

```
public
boolean isRemovable()
```

Queries the system about the removability of this memory.

Returns

true when this type of memory is removable.

onInsertion(long, long, AsyncEvent)

Signature

```
public
void onInsertion(long base,
                 long size,
                 AsyncEvent ae)
```

Register the specified [AsyncEvent](#)² to fire when any memory of this type in the range is added to the system.

Parameters

base The starting address in physical memory.

size The size of the memory area.

ae The async event to fire.

Throws

²Section [8.4.3.4](#)

`IllegalArgumentException` when `ae` is `null`, or when the specified range contains no removable memory of this type. `IllegalArgumentException` may also be thrown when `size` is less than zero.

`OffsetOutOfBoundsException` when `base` is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

onRemoval(long, long, AsyncEvent)

Signature

```
public
void onRemoval(long base,
               long size,
               AsyncEvent ae)
```

Register the specified AE to fire when any memory in the range is removed from the system.

Parameters

base The starting address in physical memory.

size The size of the memory area.

ae The async event to register.

Throws

`IllegalArgumentException` when the specified range contains no removable memory of this type, when `ae` is `null`, or when `size` is less than zero.

`OffsetOutOfBoundsException` when `base` is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

unregisterInsertionEvent(long, long, AsyncEvent)

Signature

```
public
boolean unregisterInsertionEvent(long base,
                                long size,
                                AsyncEvent ae)
```

Unregister the specified insertion event. The event is only unregistered when all three arguments match the arguments used to register the event, except that `ae` of

`null` matches all values of `ae` and will unregister every `ae` that matches the address range.

Note: This method has no effect on handlers registered directly as async event handlers.

Parameters

base The starting address in physical memory associated with `ae`.

size The size of the memory area associated with `ae`.

ae The event to unregister.

Throws

`IllegalArgumentException` when `size` is less than 0.

`OffsetOutOfBoundsException` when `base` is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

Returns

True when at least one event matched the pattern, false when no such event was found.

unregisterRemovalEvent(long, long, AsyncEvent)

Signature

```
public
boolean unregisterRemovalEvent(long base,
                                long size,
                                AsyncEvent ae)
```

Unregister the specified removal event. The async event is only unregistered when all three arguments match the arguments used to register the event, except that `ae` of `null` matches all values of `ae` and will unregister every `ae` that matches the address range. Note: This method has no effect on handlers registered directly as async event handlers.

Parameters

base The starting address in physical memory associated with `ae`.

size The size of the memory area associated with `ae`.

ae The async event to unregister.

Throws

`IllegalArgumentException` when `size` is less than 0.

`OffsetOutOfBoundsException` when `base` is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

Returns

True when at least one event matched the pattern, false when no such event was found.

vFind(long, long)*Signature*

```
public
long vFind(long base,
           long size)
```

Search for virtual memory of the right type. This is important for systems where attributes are associated with particular ranges of virtual memory.

Parameters

base The address at which to start searching.

size The amount of memory to be found.

Throws

`OffsetOutOfBoundsException` when **base** is less than zero.

`SizeOutOfBoundsException` when **base** plus **size** would be greater than the physical addressing range of the processor.

`IllegalArgumentException` when **base** or **size** is negative. `IllegalArgumentException` may also be when **base** is an invalid virtual address.

Returns

The address where memory was found or -1 when it was not found.

15.3.2 Exceptions

15.3.2.1 DuplicateFilterException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      javax.realtime.DuplicateFilterException
```

`PhysicalMemoryManager`³ can only accommodate one filter object for each type of memory. It throws this exception when an attempt is made to register more than one filter for a type of memory.

³Section 15.3.3.6

15.3.2.1.1 Constructors

DuplicateFilterException

Signature

```
public  
DuplicateFilterException()
```

A constructor for DuplicateFilterException.

DuplicateFilterException(String)

Signature

```
public  
DuplicateFilterException(String description)
```

A descriptive constructor for DuplicateFilterException.

Parameters

`description` Description of the error.

15.3.2.2 UnknownHappeningException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javax.realtime.UnknownHappeningException
```

This exception is used to indicate a situation where an instance of [AsyncEvent](#)⁴ attempts to bind to a happening that does not exist.

15.3.2.2.1 Constructors

⁴Section [8.4.3.4](#)

UnknownHappeningException

Signature

```
public  
UnknownHappeningException()
```

A constructor for UnknownHappeningException.

UnknownHappeningException(String)

Signature

```
public  
UnknownHappeningException(String description)
```

A descriptive constructor for UnknownHappeningException.

Parameters

description Description of the error.

15.3.3 Classes

15.3.3.1 ImmortalPhysicalMemory

Inheritance

```
java.lang.Object  
  javax.realtime.MemoryArea  
    javax.realtime.ImmortalPhysicalMemory
```

An instance of `ImmortalPhysicalMemory` allows objects to be allocated from a range of physical memory with particular attributes, determined by their memory type. This memory area has the same restrictive set of assignment rules as `ImmortalMemory`⁵ memory areas, and may be used in any execution context where `ImmortalMemory` is appropriate.

No provision is made for sharing object in `ImmortalPhysicalMemory` with entities outside the JVM that creates them, and, while the memory backing an instance of `ImmortalPhysicalMemory` could be shared by multiple JVMs, the class does not support such sharing.

⁵Section 11.4.2.2

Methods from `ImmortalPhysicalMemory` should be overridden only by methods that use `super`.

15.3.3.1.1 Constructors

`ImmortalPhysicalMemory(Object, long)`

Signature

```
public
    ImmortalPhysicalMemory(Object type,
                           long size)
```

Create an instance with the given parameters.

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁶ has been registered with the `PhysicalMemoryManager`⁷.

`MemoryTypeConflictException` when **type** specifies incompatible memory attributes.

`IllegalArgumentException` when **size** is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

`SizeOutOfBoundsException` when the **size** extends into an invalid range of memory.

⁶Section [15.3.1.1](#)

⁷Section [15.3.3.6](#)

ImmutablePhysicalMemory(Object, long, long)

Signature

```
public  
ImmutablePhysicalMemory(Object type,  
                        long base,  
                        long size)
```

Create an instance with the given parameters.

Parameters

type An instance of `Object` or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`SizeOutOfBoundsException` when the **size** extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁸ has been registered with the `PhysicalMemoryManager`⁹.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`IllegalArgumentException` when **size** is less than zero. `IllegalArgumentException` may also be when **base** plus **size** would be greater than the maximum physical address supported by the processor.

`MemoryInUseException` when the specified memory is already in use.

`OutOfMemoryError` when there is insufficient memory for the `ImmutablePhys-`

⁸Section 15.3.1.1

⁹Section 15.3.3.6

icalMemory object or for the backing memory.

ImmortalPhysicalMemory(Object, SizeEstimator)

Signature

```
public
    ImmortalPhysicalMemory(Object type,
                           SizeEstimator size)
```

Create an instance with the given parameters.

Parameters

type An instance of `Object` or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size A size estimator for this area.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`SizeOutOfBoundsException` when the size estimate from **size** extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁰ has been registered with the `PhysicalMemoryManager`¹¹.

`MemoryTypeConflictException` when **type** specifies incompatible memory attributes.

`IllegalArgumentException` when **size** is `null`, or `size.getEstimate()` is negative.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

ImmortalPhysicalMemory(Object, long, SizeEstimator)

¹⁰Section 15.3.1.1

¹¹Section 15.3.3.6

Signature

```
public
ImmortalPhysicalMemory(Object type,
                        long base,
                        SizeEstimator size)
```

Create an instance with the given parameters.

Parameters

type An instance of `Object` or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`SizeOutOfBoundsException` when the size estimate from **size** extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹² has been registered with the `PhysicalMemoryManager`¹³.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`IllegalArgumentException` when **size** is `null`, or `size.getEstimate()` is negative. `IllegalArgumentException` may also be when **base** plus the size indicated by **size** would be greater than the maximum physical address supported by the processor.

`MemoryInUseException` when the specified memory is already in use.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

ImmortalPhysicalMemory(Object, long, Runnable)

¹²Section 15.3.1.1

¹³Section 15.3.3.6

Signature

```
public
    ImmortalPhysicalMemory(Object type,
                           long size,
                           Runnable logic)
```

Create an instance with the given parameters.

Parameters

type An instance of `Object` or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`¹⁴ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`SizeOutOfBoundsException` when **size** extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁵ has been registered with the `PhysicalMemoryManager`¹⁶.

`IllegalArgumentException` when **size** is negative.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

`IllegalAssignmentError` when storing **logic** in **this** would violate the assignment rules.

¹⁴Section [11.4.2.3.2](#)

¹⁵Section [15.3.1.1](#)

¹⁶Section [15.3.3.6](#)

ImmortalPhysicalMemory(Object, long, long, Runnable)

Signature

```
public
ImmortalPhysicalMemory(Object type,
                        long base,
                        long size,
                        Runnable logic)
```

Create an instance with the given parameters.

Parameters

type An instance of `Object` or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size The size of the area in bytes.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`¹⁷ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`SizeOutOfBoundsException` when **size** extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁸ has been registered with the `PhysicalMemoryManager`¹⁹.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`IllegalArgumentException` when **size** is negative. `IllegalArgumentException`

¹⁷Section 11.4.2.3.2

¹⁸Section 15.3.1.1

¹⁹Section 15.3.3.6

ception may also be when **base** plus **size** would be greater than the maximum physical address supported by the processor.

MemoryInUseException when the specified memory is already in use.

OutOfMemoryError when there is insufficient memory for the **ImmortalPhysicalMemory** object or for the backing memory.

IllegalAssignmentError when storing **logic** in **this** would violate the assignment rules.

ImmortalPhysicalMemory(Object, SizeEstimator, Runnable)

Signature

```
public
ImmortalPhysicalMemory(Object type,
                        SizeEstimator size,
                        Runnable logic)
```

Create an instance with the given parameters.

Parameters

type An instance of **Object** or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

size A size estimator for this area.

logic The **run()** method of this object will be called whenever **MemoryArea.enter()**²⁰ is called. When **logic** is **null**, **logic** must be supplied when the memory area is entered.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

SizeOutOfBoundsException when the **size** extends into an invalid range of memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**²¹

²⁰Section 11.4.2.3.2

²¹Section 15.3.1.1

has been registered with the [PhysicalMemoryManager](#)²².

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is negative.

`MemoryTypeConflictException` when `type` specifies incompatible memory attributes.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

`IllegalAssignmentError` when storing logic in `this` would violate the assignment rules.

ImmortalPhysicalMemory(Object, long, SizeEstimator, Runnable)

Signature

```
public
ImmortalPhysicalMemory(Object type,
                        long base,
                        SizeEstimator size,
                        Runnable logic)
```

Create an instance with the given parameters.

Parameters

type An instance of `Object` or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is null or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

logic The `run()` method of this object will be called whenever [MemoryArea.enter\(\)](#)²³ is called. When **logic** is null, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

²²Section [15.3.3.6](#)

²³Section [11.4.2.3.2](#)

`OffsetOutOfBoundsException` when the `base` address is invalid.

`SizeOutOfBoundsException` when the size estimate from `size` extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`²⁴ has been registered with the `PhysicalMemoryManager`²⁵.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is negative. `IllegalArgumentException` may also be when `base` plus the size indicated by `size` would be greater than the maximum physical address supported by the processor.

`MemoryInUseException` when the specified memory is already in use.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

`IllegalAssignmentError` when storing logic in `this` would violate the assignment rules.

15.3.3.2 LTMemory

Inheritance

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.ScopedMemory
      javax.realtime.LTMemory
```

`LTMemory` represents a memory area guaranteed by the system to have linear time allocation when memory consumption from the memory area is less than the memory area's *initial* size. Execution time for allocation is allowed to vary when memory consumption is between the initial size and the maximum size for the area. Furthermore, the underlying system is not required to guarantee that memory between initial and maximum will always be available.

The memory area described by a `LTMemory` instance does not exist in the Java heap, and is not subject to garbage collection. Thus, it is safe to use a `LTMemory` object as the initial memory area associated with a `NoHeapRealtimeThread`²⁶,

²⁴Section 15.3.1.1

²⁵Section 15.3.3.6

²⁶Section 15.3.3.4

or to enter the memory area using the `ScopedMemory.enter`²⁷ method within a `NoHeapRealtimeThread`²⁸.

Enough memory must be committed by the completion of the constructor to satisfy the initial memory requirement. (Committed means that this memory must always be available for allocation). The initial memory allocation must behave, with respect to successful allocation, as if it were contiguous; i.e., a correct implementation must guarantee that any sequence of object allocations that could ever succeed without exceeding a specified initial memory size will always succeed without exceeding that initial memory size and succeed for any instance of `LTMemory` with that initial memory size. (Note: to ensure that all requested memory is available set initial and maximum to the same value) Methods from `LTMemory` should be overridden only by methods that use `super`.

See Section [MemoryArea](#)

See Section [ScopedMemory](#)

See Section [RealtimeThread](#)

See Section [NoHeapRealtimeThread](#)

15.3.3.2.1 Constructors

`LTMemory(long, long)`

Signature

```
public
    LTMemory(long initial,
              long maximum)
```

Create an `LTMemory` of the given size.

Parameters

initial The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

maximum The size in bytes of the memory to allocate for this area.

²⁷Section [15.3.3.11.2](#)

²⁸Section [15.3.3.4](#)

Throws

`IllegalArgumentException` when `initial` is greater than `maximum`, or when `initial` or `maximum` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

LTMemory(long, long, Runnable)

Signature

```
public
LTMemory(long initial,
         long maximum,
         Runnable logic)
```

Create an `LTMemory` of the given size.

Parameters

`initial` The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

`maximum` The size in bytes of the memory to allocate for this area.

`logic` The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LTMemory(long initial, long maximum)`²⁹.

Throws

`IllegalArgumentException` when `initial` is greater than `maximum`, or when `initial` or `maximum` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

LTMemory(SizeEstimator, SizeEstimator)

Signature

```
public
LTMemory(SizeEstimator initial,
```

²⁹Section [15.3.3.2.1](#)

SizeEstimator maximum)

Create an LTMemory of the given size.

Parameters

initial An instance of [SizeEstimator](#)³⁰ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

maximum An instance of [SizeEstimator](#)³¹ used to give an estimate for the maximum bytes to allocate for this area.

Throws

`IllegalArgumentException` when **initial** is null, **maximum** is null, **initial.getEstimate()** is greater than **maximum.getEstimate()**, or when **initial.getEstimate()** is less than zero.

`OutOfMemoryError` when there is insufficient memory for the LTMemory object or for the backing memory.

LTMemory(SizeEstimator, SizeEstimator, Runnable)

Signature

```
public
LTMemory(SizeEstimator initial,
          SizeEstimator maximum,
          Runnable logic)
```

Create an LTMemory of the given size.

Parameters

initial An instance of [SizeEstimator](#)³² used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

maximum An instance of [SizeEstimator](#)³³ used to give an estimate for the maximum bytes to allocate for this area.

logic The `run()` of the given `Runnable` will be executed using **this** as its initial memory area. When **logic** is null, this constructor is equivalent to [LTMemory\(SizeEstimator initial, SizeEstimator maximum\)](#)³⁴.

³⁰Section [11.4.2.5](#)

³¹Section [11.4.2.5](#)

³²Section [11.4.2.5](#)

³³Section [11.4.2.5](#)

³⁴Section [15.3.3.2.1](#)

Throws

`IllegalArgumentException` when `initial` is `null`, `maximum` is `null`, `initial.getEstimate()` is greater than `maximum.getEstimate()`, or when `initial.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

LTMemory(long)

Signature

```
public
LTMemory(long size)
```

Create an `LTMemory` of the given size. This constructor is equivalent to `LTMemory(size, size)`

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

LTMemory(long, Runnable)

Signature

```
public
LTMemory(long size,
          Runnable logic)
```

Create an `LTMemory` of the given size. This constructor is equivalent to `LTMemory(size, size, logic)`.

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

`logic` The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LTMemory(long size)`³⁵.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

LTMemory(SizeEstimator)

Signature

```
public
LTMemory(SizeEstimator size)
```

Create an `LTMemory` of the given size. This constructor is equivalent to `LTMemory(size, size)`.

Parameters

`size` An instance of `SizeEstimator`³⁶ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

LTMemory(SizeEstimator, Runnable)

Signature

```
public
LTMemory(SizeEstimator size,
          Runnable logic)
```

³⁵Section 15.3.3.2.1

³⁶Section 11.4.2.5

Create an `LMemory` of the given size.

Parameters

size An instance of `SizeEstimator`³⁷ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

logic The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LMemory(SizeEstimator initial)`³⁸.

Throws

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

15.3.3.2.2 Methods

toString

Signature

```
public  
java.lang.String toString()
```

Create a string representation of this object. The string is of the form `(LMemory) Scoped memory # num` where `num` uniquely identifies the `LMemory` area.

Returns

A string representing the value of `this`.

15.3.3.3 LTPhysicalMemory

Inheritance

³⁷Section 11.4.2.5

³⁸Section 15.3.3.2.1

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.memory.ScopedMemory
      javax.realtime.LTPhysicalMemory
```

An instance of `LTPhysicalMemory` allows objects to be allocated from a range of physical memory with particular attributes, determined by their memory type. This memory area has the same semantics as `ScopedMemory`³⁹ memory areas, and the same performance restrictions as `LTMemory`⁴⁰.

No provision is made for sharing object in `LTPhysicalMemory` with entities outside the JVM that creates them, and, while the memory backing an instance of `LTPhysicalMemory` could be shared by multiple JVMs, the class does not support such sharing.

Methods from `LTPhysicalMemory` should be overridden only by methods that use `super`.

15.3.3.3.1 Constructors

`LTPhysicalMemory(Object, long)`

Signature

```
public
LTPhysicalMemory(Object type,
                  long size)
```

Create an instance of `LTPhysicalMemory` with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

³⁹Section [15.3.3.11](#)

⁴⁰Section [15.3.3.2](#)

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

IllegalArgumentException when **size** is less than zero.

SizeOutOfBoundsException when the implementation detects **size** extends beyond physically addressable memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁴¹ has been registered with the **PhysicalMemoryManager**⁴².

MemoryTypeConflictException when **type** specifies incompatible memory attributes.

LTPhysicalMemory(Object, long, long)*Signature*

```
public
LTPhysicalMemory(Object type,
                  long base,
                  long size)
```

Create an instance of **LTPhysicalMemory** with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

base The physical memory address of the area.

size The size of the area in bytes.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

⁴¹Section [15.3.1.1](#)

⁴²Section [15.3.3.6](#)

SizeOutOfBoundsException when the size is less than zero, or the implementation detects that **base** plus **size** extends beyond physically addressable memory.

OffsetOutOfBoundsException when the address is invalid.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁴³ has been registered with the **PhysicalMemoryManager**⁴⁴.

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is less than zero.

MemoryInUseException when the specified memory is already in use.

LTPPhysicalMemory(Object, SizeEstimator)

Signature

```
public
LTPPhysicalMemory(Object type,
                  SizeEstimator size)
```

Create an instance of **LTPPhysicalMemory** with the given parameters.

See Section **PhysicalMemoryManager**

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

size A size estimator for this area.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

SizeOutOfBoundsException when the implementation detects that **size** extends beyond physically addressable memory.

⁴³Section 15.3.1.1

⁴⁴Section 15.3.3.6

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁴⁵ has been registered with the `PhysicalMemoryManager`⁴⁶.

`MemoryTypeConflictException` when type specifies incompatible memory attributes.

`IllegalArgumentException` when size is null, or `size.getEstimate()` is negative.

LTPhysicalMemory(Object, long, SizeEstimator)

Signature

```
public
LTPhysicalMemory(Object type,
                  long base,
                  SizeEstimator size)
```

Create an instance of `LTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is null or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`SizeOutOfBoundsException` when the implementation detects that **base** plus the size estimate extends beyond physically addressable memory.

`OffsetOutOfBoundsException` when the address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does

⁴⁵Section [15.3.1.1](#)

⁴⁶Section [15.3.3.6](#)

not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁴⁷ has been registered with the `PhysicalMemoryManager`⁴⁸.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

`MemoryInUseException` when the specified memory is already in use.

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is negative.

LTPPhysicalMemory(Object, long, Runnable)

Signature

```
public
LTPPhysicalMemory(Object type,
                   long size,
                   Runnable logic)
```

Create an instance of `LTPPhysicalMemory` with the given parameters.

See Section `PhysicalMemoryManager`

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, `type` may be an array of objects. When `type` is null or a reference to an array with no entries, any type of memory is acceptable. Note that `type` values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`⁴⁹ is called. When `logic` is null, `logic` must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`IllegalArgumentException` when `size` is less than zero.

⁴⁷Section 15.3.1.1

⁴⁸Section 15.3.3.6

⁴⁹Section 11.4.2.3.2

`SizeOutOfBoundsException` when the implementation detects that `size` extends beyond physically addressable memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁵⁰ has been registered with the `PhysicalMemoryManager`⁵¹.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

`IllegalAssignmentError` when storing logic in `this` would violate the assignment rules.

LTPhysicalMemory(Object, long, long, Runnable)

Signature

```
public
LTPhysicalMemory(Object type,
                  long base,
                  long size,
                  Runnable logic)
```

Create an instance of `LTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, `type` may be an array of objects. When `type` is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that `type` values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size The size of the area in bytes.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`⁵² is called. When `logic` is `null`, `logic` must be supplied when the memory area is entered.

⁵⁰Section [15.3.1.1](#)

⁵¹Section [15.3.3.6](#)

⁵²Section [11.4.2.3.2](#)

Throws

`SizeOutOfBoundsException` when the implementation detects that `base` plus `size` extends beyond physically addressable memory.

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`IllegalArgumentException` when `size` is less than zero.

`OffsetOutOfBoundsException` when the address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁵³ has been registered with the `PhysicalMemoryManager`⁵⁴.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

`MemoryInUseException` when the specified memory is already in use.

`IllegalAssignmentError` when storing logic in `this` would violate the assignment rules.

LTPPhysicalMemory(Object, SizeEstimator, Runnable)*Signature*

```
public
LTPPhysicalMemory(Object type,
                  SizeEstimator size,
                  Runnable logic)
```

Create an instance of `LTPPhysicalMemory` with the given parameters.

See Section `PhysicalMemoryManager`

Parameters

`type` An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, `type` may be an array of objects. When `type` is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that `type` values are compared by reference (`==`), not by value (`equals`).

⁵³Section [15.3.1.1](#)

⁵⁴Section [15.3.3.6](#)

size A size estimator for this area.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`⁵⁵ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

SizeOutOfBoundsException when the implementation detects that **base** plus the size estimate extends beyond physically addressable memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁵⁶ has been registered with the **PhysicalMemoryManager**⁵⁷.

MemoryTypeConflictException when the specified **base** does not point to memory that matches the request type, or when **type** specifies attributes with a conflict.

IllegalArgumentException when **size** is `null`, or `size.getEstimate()` is negative.

IllegalAssignmentError when storing **logic** in this would violate the assignment rules.

LTPhysicalMemory(Object, long, SizeEstimator, Runnable)

Signature

```
public
LTPhysicalMemory(Object type,
                  long base,
                  SizeEstimator size,
                  Runnable logic)
```

Create an instance of **LTPhysicalMemory** with the given parameters.

See Section **PhysicalMemoryManager**

Parameters

⁵⁵Section 11.4.2.3.2

⁵⁶Section 15.3.1.1

⁵⁷Section 15.3.3.6

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`⁵⁸ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`SizeOutOfBoundsException` when the implementation detects that **base** plus the size estimate extends beyond physically addressable memory.

`OffsetOutOfBoundsException` when the address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁵⁹ has been registered with the `PhysicalMemoryManager`⁶⁰.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`MemoryInUseException` when the specified memory is already in use.

`IllegalArgumentException` when **size** is `null`, or `size.getEstimate()` is negative.

`IllegalAssignmentError` when storing **logic** in this would violate the assignment rules.

15.3.3.3.2 Methods

toString

⁵⁸Section 11.4.2.3.2

⁵⁹Section 15.3.1.1

⁶⁰Section 15.3.3.6

Signature

```
public  
java.lang.String toString()
```

Creates a string describing this object. The string is of the form (LTPhysicalMemory) Scoped memory # num where num is a number that uniquely identifies this LTPhysicalMemory memory area, representing the value of `this`.

Returns

A string representing the value of `this`.

15.3.3.4 NoHeapRealtimeThread

Inheritance

```
java.lang.Object  
  java.lang.Thread  
    javax.realtime.RealtimeThread  
      javax.realtime.NoHeapRealtimeThread
```

A `NoHeapRealtimeThread` is a specialized form of `RealtimeThread`⁶¹. Because an instance of `NoHeapRealtimeThread` may immediately preempt any implemented garbage collector, logic contained in its `run()` is never allowed to allocate or reference any object allocated in the heap. At the byte-code level, it is illegal for a reference to an object allocated in heap to appear on a no-heap realtime thread's operand stack.

Thus, it is always safe for a `NoHeapRealtimeThread` to interrupt the garbage collector at any time, without waiting for the end of the garbage collection cycle or a defined preemption point. Due to these restrictions, a `NoHeapRealtimeThread` object must be placed in a memory area such that thread logic may unexceptionally access instance variables and such that Java methods on `Thread` (e.g., `enumerate` and `join`) complete normally except where execution would cause access violations. The constructors of `NoHeapRealtimeThread` require a reference to `ScopedMemory`⁶² or `ImmortalMemory`⁶³.

When the thread is started, all execution occurs in the scope of the given memory area. Thus, all memory allocation performed with the *new* operator is taken from this given area.

⁶¹Section 5.3.2.2

⁶²Section 15.3.3.11

⁶³Section 11.4.2.2

15.3.3.4.1 Constructors

NoHeapRealtimeThread(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, ProcessingGroupParameters, Runnable)

Signature

```
public  
NoHeapRealtimeThread(SchedulingParameters scheduling,  
                      ReleaseParameters release,  
                      MemoryParameters memory,  
                      MemoryArea area,  
                      ProcessingGroupParameters group,  
                      Runnable logic)
```

Create a realtime thread with the given characteristics and a Runnable. The thread group of the new thread is (effectively) null. The newly-created no-heap real-time thread is associated with the scheduler in effect during execution of the constructor.

Parameters

scheduling the SchedulingParameters associated with this (and possibly other instances of Schedulable). When scheduling is null, the default is a copy of the creator's scheduling parameters created in the same memory area as the new NoHeapRealtimeThread.

release the ReleaseParameters associated with this (and possibly other instances of Schedulable). When release is null the it defaults to the a copy of the creator's release parameters created in the same memory area as the new NoHeapRealtimeThread.

memory the MemoryParameters associated with this (and possibly other instances of Schedulable). When memory is null, the new NoHeapRealtimeThread will have a null value for its memory parameters, and the amount or rate of memory allocation is unrestricted.

area the MemoryArea associated with this. When area is null, an IllegalArgumentException is thrown.

group the ProcessingGroupParameters associated with this (and possibly other instances of Schedulable). When null, the new NoHeapRealtimeThread will not be associated with any processing group.

logic the Runnable object whose run() method will serve as the logic for the new NoHeapRealtimeThread. When logic is null, the run() method in the new object will serve as its logic.

Throws

IllegalArgumentException when the parameters are not compatible with the associated scheduler, when area is null, when area is heap memory, when area, scheduling release, memory or group is allocated in heap memory. when this is in heap memory, or when logic is in heap memory.

IllegalAssignmentError when the new NoHeapRealtimeThread instance cannot hold references to non-null values of the scheduling release, memory and group, or when those parameters cannot hold a reference to the new NoHeapRealtimeThread.

NoHeapRealtimeThread(SchedulingParameters, ReleaseParameters, MemoryArea)

Signature

```
public  
NoHeapRealtimeThread(SchedulingParameters scheduling,  
                      ReleaseParameters release,  
                      MemoryArea area)
```

Create a no-heap realtime thread with the given [SchedulingParameters](#)⁶⁴, [ReleaseParameters](#)⁶⁵ and [MemoryArea](#)⁶⁶, and default values for all other parameters. This constructor is equivalent to `NoHeapRealtimeThread(scheduling, release, null, area, null, null, null)`.

NoHeapRealtimeThread(SchedulingParameters, MemoryArea)

Signature

```
public  
NoHeapRealtimeThread(SchedulingParameters scheduling,  
                      MemoryArea area)
```

⁶⁴Section [6.4.2.13](#)

⁶⁵Section [6.4.2.9](#)

⁶⁶Section [11.4.2.3](#)

Create a realtime thread with the given [SchedulingParameters](#)⁶⁷ and [MemoryArea](#)⁶⁸ and default values for all other parameters.

This constructor is equivalent to `NoHeapRealtimeThread(scheduling, null, null, area, null, null, null)`.

15.3.3.4.2 Methods

start

Signature

```
public  
void start()
```

[See Section RealtimeThread.start\(\)](#)

startPeriodic(PhasingPolicy)

Signature

```
public  
void startPeriodic(PhasingPolicy phasingPolicy)  
throws LateStartException
```

[See Section RealtimeThread.startPeriodic\(PhasingPolicy\)](#)

15.3.3.5 POSIXSignalHandler

Inheritance

```
java.lang.Object  
  javax.realtime.POSIXSignalHandler
```

This class enables the use of an `AsyncEventHandler` to react on the occurrence of POSIX signals.

⁶⁷Section [6.4.2.13](#)

⁶⁸Section [11.4.2.3](#)

On systems that support POSIX signals fully, the 13 signals required by POSIX will be supported. Any further signals defined in this class may be supported by the system. On systems that do not support POSIX signals, even the 13 standard signals may never be fired.

15.3.3.5.1 Fields

SIGHUP

`public static final SIGHUP`
Hangup (POSIX).

SIGINT

`public static final SIGINT`
interrupt (ANSI)

SIGQUIT

`public static final SIGQUIT`
quit (POSIX)

SIGILL

`public static final SIGILL`
illegal instruction (ANSI)

SIGTRAP

`public static final SIGTRAP`
trace trap (POSIX), optional signal.

SIGABRT

`public static final SIGABRT`
Abort (ANSI).

SIGBUS

`public static final SIGBUS`
BUS error (4.2 BSD), optional signal.

SIGFPE

`public static final SIGFPE`
floating point exception

SIGKILL

`public static final SIGKILL`
Kill, unblockable (POSIX).

SIGUSR1

`public static final SIGUSR1`
User-defined signal 1 (POSIX).

SIGSEGV

`public static final SIGSEGV`
Segmentation violation (ANSI).

SIGUSR2

`public static final SIGUSR2`
User-defined signal 2 (POSIX).

SIGPIPE

`public static final SIGPIPE`
Broken pipe (POSIX).

SIGALRM

`public static final SIGALRM`
Alarm clock (POSIX).

SIGTERM

`public static final SIGTERM`
Termination (ANSI).

SIGCHLD

`public static final SIGCHLD`
Child status has changed (POSIX).

SIGCONT

`public static final SIGCONT`
Continue (POSIX), optional signal.

SIGSTOP

`public static final SIGSTOP`
Stop, unblockable (POSIX), optional signal.

SIGTSTP

`public static final SIGTSTP`
Keyboard stop (POSIX), optional signal.

SIGTTIN

`public static final SIGTTIN`
Background read from tty (POSIX), optional signal.

SIGTTOU

`public static final SIGTTOU`
Background write to tty (POSIX), optional signal.

SIGURG

`public static final SIGURG`
Urgent condition on socket (4.2 BSD).

SIGXCPU

`public static final SIGXCPU`
CPU limit exceeded (4.2 BSD).

SIGXFSZ

`public static final SIGXFSZ`
File size limit exceeded (4.2 BSD).

SIGVTALRM

`public static final SIGVTALRM`
Virtual alarm clock (4.2 BSD).

SIGPROF

`public static final SIGPROF`
Profiling alarm clock (4.2 BSD).

SIGWINCH

`public static final SIGWINCH`
Window size change (4.3 BSD, Sun).

SIGIO

`public static final SIGIO`
I/O now possible (4.2 BSD).

SIGPWR

`public static final SIGPWR`
Power failure restart (System V).

SIGSYS

`public static final SIGSYS`
Bad system call, optional signal.

SIGIOT

```
public static final SIGIOT
```

IOT instruction (4.2 BSD), optional signal.

SIGPOLL

```
public static final SIGPOLL
```

Pollable event occurred (System V).

SIGCLD

```
public static final SIGCLD
```

Same as SIGCHLD (System V), optional signal.

SIGEMT

```
public static final SIGEMT
```

EMT instruction, optional signal.

SIGLOST

```
public static final SIGLOST
```

SIGCANCEL

```
public static final SIGCANCEL
```

SIGFREEZE

```
public static final SIGFREEZE
```

SIGLWP

```
public static final SIGLWP
```

SIGTHAW

```
public static final SIGTHAW
```

SIGWAITING

```
public static final SIGWAITING
```

15.3.3.5.2 Constructors

POSIXSignalHandler*Signature*

```
public  
POSIXSignalHandler()
```

15.3.3.5.3 Methods

addHandler(int, AsyncEventHandler)*Signature*

```
public static  
void addHandler(int signal,  
                 AsyncEventHandler handler)
```

addHandler adds the handler provided to the set of handlers that will be released on the provided signal.

Parameters

signal The POSIX signal as defined in the constants SIG*.

handler the handler to be released on the given signal.

Throws

IllegalArgumentException iff signal is not defined by any of the constants in this class or handler is **null**.

removeHandler(int, AsyncEventHandler)

Signature

```
public static  
void removeHandler(int signal,  
                    AsyncEventHandler handler)
```

removeHandler removes a handler that was added for a given signal.

Parameters

signal The POSIX signal as defined in the constants SIG*.

handler the handler to be removed from the given signal. When this handler is null or has not been added to the signal, nothing will happen.

Throws

IllegalArgumentException iff signal is not defined by any of the constants in this class.

setHandler(int, AsyncEventHandler)

Signature

```
public static  
void setHandler(int signal,  
                AsyncEventHandler handler)
```

setHandler sets the set of handlers that will be released on the provided signal to the set with the provided handler being the single element.

Parameters

signal The POSIX signal as defined in the constants SIG*.

handler the handler to be released on the given signal, null to remove all handlers for the given signal.

Throws

IllegalArgumentException iff signal is not defined by any of the constants in this class.

15.3.3.6 PhysicalMemoryManager

Inheritance

```
java.lang.Object  
  javax.realtime.PhysicalMemoryManager
```

The `PhysicalMemoryManager` is not ordinarily used by applications, except that the implementation may require the application to use the `registerFilter`⁶⁹ method to make the physical memory manager aware of the memory types on their platform. The `PhysicalMemoryManager` class is primarily intended for use by the various physical memory accessor objects (`VTPhysicalMemory`⁷⁰, `LTPhysicalMemory`⁷¹, and `ImmortalPhysicalMemory`⁷²) to create objects of the types requested by the application. The physical memory manager is responsible for finding areas of physical memory with the appropriate characteristics and access rights, and moderating any required combination of physical and virtual memory characteristics.

The Physical Memory Manager assumes that the physical address space is linear but not necessarily contiguous. That is, addresses range from 0 .. `MAX_LONG` but there may be holes in the memory space. Some of these holes may be filled with removable memory.

The physical memory is partitioned into chunks (pages, segments, etc.). Each chunk of memory has a base address and a length.

Each chunk of memory has certain properties. Some of these properties may require actions to be performed by the Physical Memory Manager when the memory is accessed. For example, access to `IO_PAGE` may require the use of special instructions to even reach the devices, or it may require special code sequences to ensure proper handling of processor write queues and caches.

Filters tell the Physical Memory Manager about the properties of the memory that are available on the machine by registering with the Physical Memory Manager.

When the program requests a physical memory area with particular properties, the constructor communicates with the Physical Memory Manager through a private interface. The Physical Memory Manager asks the filter if the address specified has the required properties and whether it is free, or asks for a chunk of memory with the requested size.

The Physical Memory Manager then maps the physical memory chunk into virtual memory (on systems that support virtual memory). and locks the virtual memory to the memory chunk.

Examples of characteristics that might be specified are: DMA memory, hardware byte swapping, non-cached access to memory, etc. Standard "names" for some memory characteristics are included in this class — `DMA`, `SHARED`, `ALIGNED`, `BYTESWAP`, and `IO_PAGE` — support for these characteristics is optional, but when they are supported they must use these names. Additional characteristics may be supported, but only names defined in this specification may be visible in the `PhysicalMemoryManager` API.

⁶⁹Section 15.3.3.6.2

⁷⁰Section 15.3.3.13

⁷¹Section 15.3.3.3

⁷²Section 15.3.3.1

The base implementation will provide a `PhysicalMemoryManager`.

Original Equipment Manufacturers or other interested parties may provide `PhysicalMemoryTypeFilter`⁷³ classes that allow additional characteristics of memory devices to be specified.

15.3.3.6.1 Fields

ALIGNED

```
public static final ALIGNED
```

When aligned memory is supported by the implementation specify **ALIGNED** to identify aligned memory. This type of memory ignores low-order bits in load and store accesses to force accesses to fall on natural boundaries for the access type even when the processor uses a poorly aligned address.

BYTESWAP

```
public static final BYTESWAP
```

When automatic byte swapping is supported by the implementation specify **BYTESWAP** when byte swapping should be used. Byte-swapping memory re-orders the bytes in accesses for 16 bits or more such that little-endian data in memory is accessed as big-endian, and vice-versa. Such memory would typically be available in swapped mode in one physical address range and in un-swapped mode in another address range.

DMA

```
public static final DMA
```

When DMA (Direct Memory Access) memory is supported by the implementation, specify **DMA** to identify DMA memory. This memory is visible to devices that use DMA. In some systems, only a portion of the physical address space is available to DMA devices. On such systems, memory that will be used for DMA must be allocated from the range of addresses that DMA can reach.

⁷³Section 15.3.1.1

IO_PAGE

```
public static final IO_PAGE
```

When access to the system I/O space is supported by the implementation specify `IO_PAGE` when I/O space should be used. Addresses tagged with the name `IO_PAGE` are used for memory mapped I/O devices. Such addresses are almost certainly not suitable for physical memory, but only for raw memory access.

SHARED

```
public static final SHARED
```

When shared memory is supported by the implementation specify `SHARED` to identify shared memory. In a NUMA (Non-Uniform Memory Access) architecture, processors may make some part of their local memory available to other processors. This memory would be tagged with `SHARED`, as would memory that is shared and non-local.

A fully built-out NUMA system might well need sub-classifications of `SHARED` to reflect different paths to memory. Note that, as with other physical memory names, a single byte of memory may be visible at several physical addresses with different access properties at each address. For instance, a byte of shared memory accesses at address *x* might be shared with high-performance access, but without the support of coherent caches. The same byte accessed at address *y* might be shared with coherent cache support, but substantially longer access times.

15.3.3.6.2 Methods

isRemovable(long, long)

Signature

```
public static  
boolean isRemovable(long base,  
                    long size)
```

Queries the system about the removability of the specified range of memory.

Parameters

base The starting address in physical memory.
size The size of the memory area.

Throws

`IllegalArgumentException` when `size` is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

`OffsetOutOfBoundsException` when `base` is less than zero.

Returns

true when any part of the specified range can be removed.

isRemoved(long, long)*Signature*

```
public static
boolean isRemoved(long base,
                  long size)
```

Queries the system about the removed state of the specified range of memory. This method is used for devices that lie in the memory address space and can be removed while the system is running. (Such as PC cards).

Parameters

base The starting address in physical memory.

size The size of the memory area.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OffsetOutOfBoundsException` when `base` is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

Returns

true when any part of the specified range is currently not usable.

onInsertion(long, long, AsyncEvent)*Signature*

```
public static
void onInsertion(long base,
                 long size,
                 AsyncEvent ae)
```

Register the specified [AsyncEvent](#)⁷⁴ to fire when any memory in the range is added to the system. When the specified range of physical memory contains multiple different types of removable memory, the AE will be registered with each of them.

Parameters

base The starting address in physical memory.
size The size of the memory area.
ae The async event to fire.

Throws

`IllegalArgumentException` when **ae** is null, or when the specified range contains no removable memory, or when **size** is less than zero.

`OffsetOutOfBoundsException` when **base** is less than zero.

`SizeOutOfBoundsException` when **base** plus **size** would be greater than the physical addressing range of the processor.

onInsertion(long, long, AsyncEventHandler)

Signature

```
public static  
void onInsertion(long base,  
                 long size,  
                 AsyncEventHandler aeh)
```

Register the specified [AsyncEventHandler](#)⁷⁵ to run when any memory in the range is added to the system. When the specified range of physical memory contains multiple different types of removable memory, the AEH will be registered with each of them. When the size or the base is less than 0, unregister all "onInsertion" references to the handler.

Note: This method only removes handlers that were registered with the same method. It has no effect on handlers that were registered using an associated async event.

Parameters

base The starting address in physical memory.
size The size of the memory area.
aeh The handler to register.

Throws

`IllegalArgumentException` when **aeh** is null, or when the specified range contains no removable memory, or when **aeh** is null and **size** and **base** are

⁷⁴Section [8.4.3.4](#)

⁷⁵Section [8.4.3.5](#)

both greater than or equal to zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

onRemoval(long, long, AsyncEvent)

Signature

```
public static
void onRemoval(long base,
               long size,
               AsyncEvent ae)
```

Register the specified AE to fire when any memory in the range is removed from the system. When the specified range of physical memory contains multiple different types of removable memory, the AE will be registered with each of them.

Parameters

base The starting address in physical memory.

size The size of the memory area.

ae The async event to register.

Throws

`IllegalArgumentException` when the specified range contains no removable memory, when `ae` is `null`, or when `size` is less than zero.

`OffsetOutOfBoundsException` when `base` is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

onRemoval(long, long, AsyncEventHandler)

Signature

```
public static
void onRemoval(long base,
               long size,
               AsyncEventHandler aeh)
```

Register the specified AEH to run when any memory in the range is removed from the system. When the specified range of physical memory contains multiple different types of removable memory, the AEH will be registered with each of them. When `size` or `base` is less than 0, unregister all "onRemoval" references to the handler parameter.

Note: This method only removes handlers that were registered with the same method. It has no effect on handlers that were registered using an associated async event.

Parameters

base The starting address in physical memory.
size The size of the memory area.
aeh The handler to register.

Throws

IllegalArgumentException when the specified range contains no removable memory, or when **aeh** is null and **size** and **base** are both greater than or equal to zero.
SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.

registerFilter(Object, PhysicalMemoryTypeFilter)

Signature

```
public static final  
void registerFilter(Object name,  
                    PhysicalMemoryTypeFilter filter)  
throws DuplicateFilterException
```

Register a memory type filter with the physical memory manager.

Values of **name** are compared using reference equality (==) not value equality (equals()).

Parameters

name The type of memory handled by this filter.
filter The filter object.

Throws

DuplicateFilterException when a filter for this type of memory already exists.
ResourceLimitError when the system is configured for a bounded number of filters. This filter exceeds the bound.
IllegalArgumentException when the name parameter is an array of objects, when the name and filter are not both in immortal memory, or when either **name** or **filter** is null.
SecurityException when this operation is not permitted.

removeFilter(Object)

Signature

```
public static final  
void removeFilter(Object name)
```

Remove the identified filter from the set of registered filters. When the filter is not registered, silently do nothing.

Values of **name** are compared using reference equality (==) not value equality (`equals()`).

Parameters

name The identifying object for this memory attribute.

Throws

`IllegalArgumentException` when **name** is null.

`SecurityException` when this operation is not permitted.

unregisterInsertionEvent(long, long, AsyncEvent)*Signature*

```
public static  
boolean unregisterInsertionEvent(long base,  
                                long size,  
                                AsyncEvent ae)
```

Unregister the specified insertion event. The event is only unregistered when all three arguments match the arguments used to register the event, except that **ae** of `null` matches all values of **ae** and will unregister every **ae** that matches the address range.

Note: This method has no effect on handlers registered directly as async event handlers.

Parameters

base The starting address in physical memory associated with **ae**.

size The size of the memory area associated with **ae**.

ae The event to unregister.

Throws

`IllegalArgumentException` when **size** is less than 0.

`OffsetOutOfBoundsException` when **base** is less than zero.

`SizeOutOfBoundsException` when **base** plus **size** would be greater than the physical addressing range of the processor.

Returns

True when at least one event matched the pattern, false when no such event was found.

unregisterRemovalEvent(long, long, AsyncEvent)

Signature

```
public static  
boolean unregisterRemovalEvent(long base,  
                                long size,  
                                AsyncEvent ae)
```

Unregister the specified removal event. The async event is only unregistered when all three arguments match the arguments used to register the event, except that **ae** of **null** matches all values of **ae** and will unregister every **ae** that matches the address range.

Note: This method has no effect on handlers registered directly as async event handlers.

Parameters

base The starting address in physical memory associated with **ae**.

size The size of the memory area associated with **ae**.

ae The async event to unregister.

Throws

IllegalArgumentException when **size** is less than 0.

OffsetOutOfBoundsException when **base** is less than zero.

SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.

Returns

True when at least one event matched the pattern, false when no such event was found.

15.3.3.7 ProcessingGroupParameters

Inheritance

java.lang.Object

javax.realtime.ProcessingGroupParameters

Interfaces

Cloneable

Serializable

This is associated with one or more schedulables for which the system guarantees that the associated objects will not be given more time per period than indicated by `cost`. The motivation for this class is to allow the execution demands of one or more aperiodic schedulables to be bound. However, periodic or sporadic schedulables can also be associated with a processing group.

Processing groups have an associated affinity set that must contain only a single processor. The default affinity set is given by `Affinity.getGroupDefaultAffinity()`.

For all schedulables with a reference to an instance of `ProcessingGroupParameters` `p` no more than `p.cost` will be allocated to the execution of these schedulables on the processor associated with its processing group in each interval of time given by `p.period` after the time indicated by `p.start`. No execution of the schedulables will be allowed on any processor other than this processor. When there is no intersection between the a schedulable objects affinity set and its processing group's affinity set, then the schedulable execution is constrained by the default processing group's affinity set.

Logically a virtual server is associated with each instance of `ProcessingGroupParameters`. This server has a start time, a period, a cost (budget) and a deadline. The server can only logically execute when (a) it has not consumed more execution time in its current release than the cost (budget) parameter, (b) one of its associated schedulables is executable and is the most eligible of the executable schedulables. When the server is logically executable, the associated schedulable is executed. When the cost has been consumed, any `overrunHandler` is released, and the server is not eligible for logical execution until its next period is due. At this point, its allocated cost (budget) is replenished. When the server is logically executing when its deadline expires, any associated `missHandler` is released. The deadline and cost parameters of all the associated schedulable objects have the same impact as they would if the objects were not bound to a processing group.

Processing group parameters use `HighResolutionTime`⁷⁶ values for cost, deadline, period and start time. Since those times are expressed as a `HighResolutionTime`⁷⁷, the values use accurate timers with nanosecond granularity. The actual resolution available and even the quantity it measures depends on the clock associated with each time value.

When a reference to a `ProcessingGroupParameters` object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's setter methods, the `ProcessingGroupParameters` object becomes the processing group parameters object bound to that schedulable object. Changes to the values in the `ProcessingGroupParameters` object affect that schedulable object. When bound to more than one schedulable then changes to the values in the `Pro-`

⁷⁶Section 9.4.1.2

⁷⁷Section 9.4.1.2

Table 15.1: ProcessingGroupParameter Default Values

Attribute	Default Value
start	new RelativeTime(0,0)
period	No default. A value must be supplied
cost	No default. A value must be supplied
deadline	new RelativeTime(period)
overrunHandler	None
missHandler	None

cessingGroupParameters object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

The implementation must use modified copy semantics for each **HighResolutionTime**⁷⁸ parameter value. The value of each time object should be treated as if it were copied at the time it is passed to the parameter object, but the object reference must also be retained. Only changes to a **ProcessingGroupParameters** object caused by methods on that object are immediately visible to the scheduler. For instance, invoking **setPeriod()** on a **ProcessingGroupParameters** object will make the change, then notify that the scheduler that the parameter object has changed. At that point the scheduler's view of the processing group parameters object is updated. Invoking a method on the **RelativeTime** object that is the period for this object may change the period but it does not pass the change to the scheduler at that time. That new value for period must not change the behavior of the SOs that use the parameter object until a setter method on the **ProcessingGroupParameters** object is invoked, or the parameter object is used in **setProcessingGroupParameters()** or a constructor for an SO.

The implementation may use copy semantics for each **HighResolutionTime** parameter value. For instance the value returned by **getCost()** must be equal to the value passed in by **setCost**, but it need not be the same object.

The following table gives the default parameter values for the constructors.

Caution: This class is explicitly unsafe in multithreaded situations when it is being changed. No synchronization is done. It is assumed that users of this class who are mutating instances will be doing their own synchronization at a higher level.

Caution: The **cost** parameter time should be considered to be measured against the target platform.

⁷⁸Section 9.4.1.2

15.3.3.7.1 Constructors

ProcessingGroupParameters(HighResolutionTime, RelativeTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
public
ProcessingGroupParameters(javax.realtime.HighResolutionTime<?> start,
                           RelativeTime period,
                           RelativeTime cost,
                           RelativeTime deadline,
                           AsyncEventHandler overrunHandler,
                           AsyncEventHandler missHandler)
throws IllegalArgumentException,
       IllegalAssignmentError
```

Create a `ProcessingGroupParameters` object.

Parameters

start Time at which the first period begins. When a `RelativeTime`, this time is relative to the creation of this. When an `AbsoluteTime`, then the first release of the logical server is at the start time (or immediately when the absolute time is in the past). When `null`, the default value is a new instance of `RelativeTime(0,0)`.

period The period is the interval between successive replenishment of the logical server's associated cost budget. There is no default value. When `period` is `null` an exception is thrown.

cost Processing time per period. The budget CPU time that the logical server can consume each period. When `null`, an exception is thrown.

deadline The latest permissible completion time measured from the start of the current period. Changing the deadline might not take effect after the expiration of the current deadline. Specifying a deadline less than the period constrains execution of all the members of the group to the beginning of each period. When `null`, the default value is new instance of `RelativeTime(period)`.

overrunHandler This handler is invoked when any schedulable object member of this processing group attempts to use processor time beyond the group's

budget. When `null`, no application async event handler is fired on the overrun condition.

missHandler This handler is invoked when the logical server is still executing after the deadline has passed. When `null`, no application async event handler is fired on the deadline miss condition.

Throws

IllegalArgumentException when the **period** is `null` or its time value is not greater than zero, when **cost** is `null`, or when the time value of **cost** is less than zero, when **start** is an instance of **RelativeTime** and its value is negative, or when the time value of **deadline** is not greater than zero and less than or equal to the **period**. When the implementation does not support processing group deadline less than period, **deadline** less than **period** will cause **IllegalArgumentException** to be thrown.

IllegalAssignmentError when **start**, **period**, **cost**, **deadline**, **overrunHandler** or **missHandler** cannot be stored in **this**.

15.3.3.7.2 Methods

clone

Signature

```
public
java.lang.Object clone()
throws CloneNotSupportedException
```

Create a clone of **this**. This method should behave effectively as when it constructed a new object with clones of the high-resolution time values of **this**.

- The new object is in the current allocation context.
- **clone** does not copy any associations from **this** and it does not implicitly bind the new object to a SO.
- The new object has clones of all high-resolution time values (deep copy).
- References to event handlers are copied (shallow copy.)

Throws

CloneNotSupportedException never

Returns

the clone of **this**

getCost

Signature

```
public  
javax.realtime.RelativeTime getCost()
```

Gets the value of `cost`.

Returns

a reference to the value of `cost`.

getCostOverrunHandler

Signature

```
public  
javax.realtime.AsyncEventHandler getCostOverrunHandler()
```

Gets the cost overrun handler.

Returns

A reference to an instance of [AsyncEventHandler](#)⁷⁹ that is cost overrun handler of `this`.

getDeadline

Signature

```
public  
javax.realtime.RelativeTime getDeadline()
```

Gets the value of `deadline`.

Returns

A reference to an instance of [RelativeTime](#)⁸⁰ that is the deadline of `this`.

getDeadlineMissHandler

Signature

```
public  
javax.realtime.AsyncEventHandler getDeadlineMissHandler()
```

⁷⁹Section [8.4.3.5](#)

⁸⁰Section [9.4.1.3](#)

Gets the deadline miss handler.

Returns

A reference to an instance of [AsyncEventHandler](#)⁸¹ that is deadline miss handler of `this`.

getPeriod

Signature

```
public  
    javax.realtime.RelativeTime getPeriod()
```

Gets the value of `period`.

Returns

A reference to an instance of [RelativeTime](#)⁸² that represents the value of `period`.

getStart

Signature

```
public  
    javax.realtime.HighResolutionTime<?> getStart()
```

Gets the value of `start`. This is the value that was specified in the constructor or by `setStart()`, not the actual absolute time the corresponding to the start of the processing group.

Returns

A reference to an instance of [HighResolutionTime](#)⁸³ that represents the value of `start`.

setCost(RelativeTime)

Signature

```
public  
    void setCost(RelativeTime cost)
```

⁸¹Section [8.4.3.5](#)

⁸²Section [9.4.1.3](#)

⁸³Section [9.4.1.2](#)

throws `IllegalArgumentException`,
 `IllegalAssignmentError`

Sets the value of `cost`.

Parameters

`cost` The new value for `cost`. When `null`, an exception is thrown.

Throws

`IllegalArgumentException` when `cost` is `null` or its time value is less than zero.

`IllegalAssignmentError` when `cost` cannot be stored in `this`.

setCostOverrunHandler(AsyncEventHandler)

Signature

```
public  
void setCostOverrunHandler(AsyncEventHandler handler)  
throws IllegalAssignmentError
```

Sets the cost overrun handler.

Parameters

`handler` This handler is invoked when the `run()` method of and of the the schedulables attempt to execute for more than `cost` time units in any period. When `null`, no handler is attached, and any previous handler is removed.

Throws

`IllegalAssignmentError` when `handler` cannot be stored in `this`.

setDeadline(RelativeTime)

Signature

```
public  
void setDeadline(RelativeTime deadline)  
throws IllegalArgumentException,  
    IllegalAssignmentError
```

Sets the value of `deadline`.

Parameters

`deadline` The new value for `deadline`. When `null`, the default value is new instance of `RelativeTime(period)`.

Throws

`IllegalArgumentException` when `deadline` has a value less than zero or greater than the period. Unless the implementation supports deadline less than period in processing groups, `IllegalArgumentException` is also when `deadline` is less than the period.

`IllegalAssignmentError` when `deadline` cannot be stored in `this`.

setDeadlineMissHandler(AsyncEventHandler)

Signature

```
public
void setDeadlineMissHandler(AsyncEventHandler handler)
throws IllegalAssignmentError
```

Sets the deadline miss handler.

Parameters

handler This handler is invoked when the `run()` method of any of the schedulables still expect to execute after the deadline has passed. When `null`, no handler is attached, and any previous handler is removed.

Throws

`IllegalAssignmentError` when `handler` cannot be stored in `this`.

setPeriod(RelativeTime)

Signature

```
public
void setPeriod(RelativeTime period)
throws IllegalArgumentException,
    IllegalAssignmentError
```

Sets the value of `period`.

Parameters

period The new value for `period`. There is no default value. When `period` is `null` an exception is thrown.

Throws

`IllegalArgumentException` when `period` is `null`, or its time value is not greater than zero. When the implementation does not support processing group deadline less than period, and `period` is not equal to the current value of the processing group's deadline, the deadline is set to a clone of `period` created in the same memory area as `period`.

`IllegalAssignmentError` when `period` cannot be stored in `this`.

setStart(HighResolutionTime)

Signature

```
public
void setStart(javax.realtime.HighResolutionTime<?> start)
throws IllegalArgumentException,
    IllegalAssignmentError
```

Sets the value of `start`. When the processing group is already started this method alters the value of this object's start time property, but has no other effect.

Parameters

`start` The new value for `start`. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

Throws

`IllegalAssignmentError` when `start` cannot be stored in this.

`IllegalArgumentException` when `start` is a relative time value and less than zero.

15.3.3.8 RationalTime

Inheritance

```
java.lang.Object
  javax.realtime.HighResolutionTime
    javax.realtime.RelativeTime
      javax.realtime.RationalTime
```

An object that represents a time interval milliseconds/ 10^3 + nanoseconds/ 10^9 seconds long that is divided into subintervals by some frequency. This is generally used in periodic events, threads, and feasibility analysis to specify periods where there is a basic period that must be adhered to strictly (the interval), but within that interval the periodic events are supposed to happen frequency times, as uniformly spaced as possible, but clock and scheduling jitter is moderately acceptable.

15.3.3.9 RawMemoryAccess

Inheritance

```
java.lang.Object
  javax.realtime.RawMemoryAccess
```

An instance of `RawMemoryAccess` models a range of physical memory as a fixed sequence of bytes. A complement of accessor methods enable the contents of the physical area to be accessed through offsets from the base, interpreted as byte, short, int, or long data values or as arrays of these types.

Whether an offset addresses the high-order or low-order byte is normally based on the value of the `RealtimeSystem.BYTE_ORDER`⁸⁴ static byte variable in class `RealtimeSystem`⁸⁵. When the type of memory used for this `RawMemoryAccess` region implements non-standard byte ordering, accessor methods in this class continue to select bytes starting at `offset` from the base address and continuing toward greater addresses. The memory type may control the mapping of these bytes into the primitive data type. The memory type could even select bytes that are not contiguous. In each case the documentation for the `PhysicalMemoryTypeFilter`⁸⁶ must document any mapping other than the "normal" one specified above.

The `RawMemoryAccess` class allows a realtime program to implement device drivers, memory-mapped I/O, flash memory, battery-backed RAM, and similar low-level software.

A raw memory area cannot contain references to Java objects. Such a capability would be unsafe (since it could be used to defeat Java's type checking) and error-prone (since it is sensitive to the specific representational choices made by the Java compiler).

Many of the constructors and methods in this class throw `OffsetOutOfBoundsException`⁸⁷. This exception means that the value given in the offset parameter is either negative or outside the memory area.

Many of the constructors and methods in this class throw `SizeOutOfBoundsException`⁸⁸. This exception means that the value given in the size parameter is either negative, larger than an allowable range, or would cause an accessor method to access an address outside of the memory area.

Unlike other integral parameters in this chapter, negative values are valid for `byte`, `short`, `int`, and `long` values that are copied in and out of memory by the `set` and `get` methods of this class.

All offset values used in this class are measured in bytes.

Atomic loads and stores on raw memory are defined in terms of physical memory. This memory may be accessible to threads outside the JVM and to non-programmed access (e.g., DMA), consequently atomic access must be supported by hardware. This specification is written with the assumption that all suitable hardware platforms support atomic loads for aligned bytes, shorts, and ints. Atomic access beyond

⁸⁴Section 13.3.1.7.1

⁸⁵Section 13.3.1.7

⁸⁶Section 15.3.1.1

⁸⁷Section 14.3.2.10

⁸⁸Section 14.3.2.14

the specified minimum may be supported by the implementation.

Storing values into raw memory is more hardware-dependent than loading values. Many processor architectures do not support atomic stores of variables except for aligned stores of the processor's word size. For instance, storing a byte into memory might require reading a 32-bit quantity into a processor register, updating the register to reflect the new byte value, then re-storing the whole 32-bit quantity. Changes to other bytes in the 32-bit quantity that take place between the load and the store will be lost.

Some processors have mechanisms that can be used to implement an atomic store of a byte, but those mechanisms are often slow and not universally supported.

This class supports unaligned access to data, but it does not require the implementation to make such access atomic. Accesses to data aligned on its natural boundary will be atomic when the processor implements atomic loads and stores of that data size.

Except where noted, accesses to raw memory are not atomic with respect to the memory or with respect to schedulables. A raw memory area could be updated by another schedulable, or even unmapped in the middle of a method.

The characteristics of raw-memory access are necessarily platform dependent. This specification provides a minimum requirement for the RTSJ platform, but it also supports optional system properties that identify a platform's level of support for atomic raw put and get. The properties represent a four-dimensional sparse array with boolean values indicating whether that combination of access attributes is atomic. The default value for array entries is false. The dimension are

The true values in the table are represented by properties of the following form. `javax.realtime.atomicaccess_<access>_<type>_<alignment>_atomicity=true` for example:

```
javax.realtime.atomicaccess_read_byte_0_memory=true
```

Table entries with a value of false may be explicitly represented, but since false is the default value, such properties are redundant.

All raw memory access is treated as volatile, and *serialized*. The run-time must be forced to re-read memory or write to memory on each call to a raw memory `getxxx` or `putxxx` method, and to complete the reads and writes in the order they appear in the program order.

15.3.3.9.1 Constructors

RawMemoryAccess(Object, long)

Table 15.2: Properties Array

Attribute	Values	Comment
Access type	read, write	
Data type	byte, short, int, long, float, double	
Alignment	0	aligned
	1 to one less than data type size	the first byte of the data is <i>alignment</i> bytes away from natural alignment.
Atomicity	processor	means access is atomic with respect to other tasks on processor.
	smp	means access is <i>processor</i> atomic, and atomic with respect to all processors in an SMP.
	memory	means that access is <i>smp</i> atomic, and atomic with respect to all access to the memory including DMA.

Signature

```
public
RawMemoryAccess(Object type,
                 long size)
```

Construct an instance of `RawMemoryAccess` with the given parameters, and set the object to the mapped state. When the platform supports virtual memory, map the raw memory into virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See `PhysicalMemoryTypeFilter.getVMAttributes`⁸⁹ and `PhysicalMemoryTypeFilter.getVMFlags`⁹⁰).

Parameters

type An instance of `Object` representing the type of memory required (e.g.,

⁸⁹Section 15.3.1.1.1

⁹⁰Section 15.3.1.1.1

dma, shared) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

size The size of the area in bytes.

Throws

SecurityException when the application doesn't have permissions to access physical memory, the specified range of addresses, or the given type of memory.

SizeOutOfBoundsException when the size is negative or extends into an invalid range of memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching [PhysicalMemoryTypeFilter](#)⁹¹ has been registered with the [PhysicalMemoryManager](#)⁹².

MemoryTypeConflictException when the specified base does not point to memory that matches the request type, or when **type** specifies incompatible memory attributes.

OutOfMemoryError when the requested type of memory exists, but there is not enough of it free to satisfy the request.

SecurityException when the application doesn't have permissions to access physical memory or the given range of memory.

RawMemoryAccess(Object, long, long)

Signature

```
public
RawMemoryAccess(Object type,
                  long base,
                  long size)
```

Construct an instance of **RawMemoryAccess** with the given parameters, and set the object to the mapped state. When the platform supports virtual memory, map the raw memory into virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the **vmFlags** and **vmAttributes** of the

⁹¹Section [15.3.1.1](#)

⁹²Section [15.3.3.6](#)

`PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See `PhysicalMemoryTypeFilter.getVMAttributes`⁹³ and `PhysicalMemoryTypeFilter.getVMFlags`⁹⁴).

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the region.

size The size of the area in bytes.

Throws

`SecurityException` when application doesn't have permissions to access physical memory, the specified range of addresses, or the given type of memory.

`OffsetOutOfBoundsException` when the address is invalid.

`SizeOutOfBoundsException` when the size is negative or extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁹⁵ has been registered with the `PhysicalMemoryManager`⁹⁶.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the request type, or when **type** specifies incompatible memory attributes.

`OutOfMemoryError` when the requested type of memory exists, but there is not enough of it free to satisfy the request.

15.3.3.9.2 Methods

getBytes(long)

Signature

⁹³Section 15.3.1.1.1

⁹⁴Section 15.3.1.1.1

⁹⁵Section 15.3.1.1

⁹⁶Section 15.3.3.6

```
public
byte getByte(long offset)
```

Gets the **byte** at the given offset in the memory area associated with this object. The byte is always loaded from memory in a single atomic operation.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See [Section **RawMemoryAccess.map\(long,long\)**](#)

Parameters

offset The offset in bytes from the beginning of the raw memory from which to load the byte.

Throws

SizeOutOfBoundsException when the object is not mapped, or when the byte falls in an invalid address range.

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException⁹⁷](#) somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SecurityException when this access is not permitted by the security manager.

Returns

The byte from raw memory.

getBytes(long, byte, int, int)

Signature

```
public
void getBytes(long offset,
               byte[] bytes,
               int low,
               int number)
```

Gets **number** bytes starting at the given offset in the memory area associated with this object and assigns them to the byte array passed starting at position **low**.

⁹⁷Section [14.3.2.14](#)

Each byte is loaded from memory in a single atomic operation. Groups of bytes may be loaded together, but this is unspecified.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See Section [RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory from which to start loading.

bytes The array into which the loaded items are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

number The number of items to load.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#)⁹⁸ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the byte falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **bytes** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

getInt(long)

Signature

```
public
int getInt(long offset)
```

⁹⁸Section [14.3.2.14](#)

Gets the `int` at the given offset in the memory area associated with this object. When the integer is aligned on a "natural" boundary it is always loaded from memory in a single atomic operation. When it is not on a natural boundary it may not be loaded atomically, and the number and order of the load operations is unspecified.

Caching of the memory access is controlled by the memory `type` requested when the `RawMemoryAccess` instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See [Section `RawMemoryAccess.map\(long,long\)`](#)

Parameters

`offset` The offset in bytes from the beginning of the raw memory area from which to load the integer.

Throws

`OffsetOutOfBoundsException` when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#)⁹⁹ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

`SizeOutOfBoundsException` when the object is not mapped, or when the integer falls in an invalid address range.

`SecurityException` when this access is not permitted by the security manager.

Returns

The integer from raw memory.

getInts(long, int, int, int)

Signature

```
public
void getInts(long offset,
             int[] ints,
             int low,
             int number)
```

Gets `number` integers starting at the given offset in the memory area associated with this object and assign them to the int array passed starting at position `low`.

⁹⁹Section [14.3.2.14](#)

When the integers are aligned on natural boundaries each integer is loaded from memory in a single atomic operation. Groups of integers may be loaded together, but this is unspecified. When the integers are not aligned on natural boundaries they may not be loaded atomically and the number and order of load operations is unspecified.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See Section [RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start loading.

ints The array into which the integers read from the raw memory are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

number The number of integers to loaded.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#)¹⁰⁰ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the integers fall in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **ints** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

getLong(long)

Signature

¹⁰⁰Section [14.3.2.14](#)

```
public  
long getLong(long offset)
```

Gets the **long** at the given offset in the memory area associated with this object. The load is not required to be atomic even it is located on a natural boundary.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to load the long.

Throws

OffsetOutOfBoundsException when the offset is invalid.

SizeOutOfBoundsException when the object is not mapped, or when the double falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

Returns

The long from raw memory.

getLongs(long, long, int, int)

Signature

```
public  
void getLongs(long offset,  
              long[] longs,  
              int low,  
              int number)
```

Gets **number** longs starting at the given offset in the memory area associated with this object and assign them to the long array passed starting at position **low**.

The loads are not required to be atomic even when they are located on natural boundaries.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See Section [RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start loading.

longs The array into which the loaded items are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

number The number of longs to load.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#)¹⁰¹ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when a long falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **longs** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

getMappedAddress

Signature

```
public  
long getMappedAddress()
```

Gets the virtual memory location at which the memory region is mapped.

Throws

IllegalStateException when the raw memory object is not in the mapped state.

Returns

The virtual address to which this is mapped (for reference purposes). Same as the base address when virtual memory is not supported.

¹⁰¹Section [14.3.2.14](#)

getShort(long)

Signature

```
public  
short getShort(long offset)
```

Gets the **short** at the given offset in the memory area associated with this object. When the short is aligned on a natural boundary it is always loaded from memory in a single atomic operation. When it is not on a natural boundary it may not be loaded atomically, and the number and order of the load operations is unspecified.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See [Section RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to load the short.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#)¹⁰² somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the short falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

Returns

The short loaded from raw memory.

getShorts(long, short, int, int)

Signature

```
public  
void getShorts(long offset,  
               short[] shorts,
```

¹⁰²Section [14.3.2.14](#)

```
int low,  
int number)
```

Gets **number** shorts starting at the given offset in the memory area associated with this object and assign them to the short array passed starting at position **low**.

When the shorts are located on natural boundaries each short is loaded from memory in a single atomic operation. Groups of shorts may be loaded together, but this is unspecified.

When the shorts are not located on natural boundaries the load may not be atomic, and the number and order of load operations is unspecified. Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See Section [RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to start loading.

shorts The array into which the loaded items are placed.

low The offset which is the starting point in the given array for the loaded shorts to be placed.

number The number of shorts to load.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#)¹⁰³ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when a short falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **shorts** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

¹⁰³Section [14.3.2.14](#)

map

Signature

```
public  
long map()
```

Maps the physical memory range into virtual memory. No-op when the system doesn't support virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See [PhysicalMemoryTypeFilter.getVMAttributes](#)¹⁰⁴ and [PhysicalMemoryTypeFilter.getVMFlags](#)¹⁰⁵).

When the object is already mapped into virtual memory, this method does not change anything.

Throws

`OutOfMemoryError` when there is insufficient free virtual address space to map the object.

Returns

The starting point of the virtual memory range.

map(long)

Signature

```
public  
long map(long base)
```

Maps the physical memory range into virtual memory at the specified location. No-op when the system doesn't support virtual memory.

The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See [PhysicalMemoryTypeFilter.getVMAttributes](#)¹⁰⁶ and [PhysicalMemoryTypeFilter.getVMFlags](#)¹⁰⁷).

When the object is already mapped into virtual memory at a different address, this method remaps it to `base`.

¹⁰⁴Section [15.3.1.1.1](#)

¹⁰⁵Section [15.3.1.1.1](#)

¹⁰⁶Section [15.3.1.1.1](#)

¹⁰⁷Section [15.3.1.1.1](#)

When a remap is requested while another schedulable is accessing the raw memory, the map will block until one load or store completes. It can interrupt an array operation between entries.

Parameters

base The location to map at the virtual memory space.

Throws

OutOfMemoryError when there is insufficient free virtual memory at the specified address.

IllegalArgumentException when **base** is not a legal value for a virtual address, or the memory-mapping hardware cannot place the physical memory at the designated address.

Returns

The starting point of the virtual memory.

map(long, long)

Signature

```
public  
long map(long base,  
         long size)
```

Maps the physical memory range into virtual memory. No-op when the system doesn't support virtual memory.

The attributes of the mapping operation are controlled by the **VMFlags** and **VMAttributes** of the **PhysicalMemoryTypeFilter** objects that matched this object's **type** parameter. (See [PhysicalMemoryTypeFilter.getVMAttributes](#)¹⁰⁸ and [PhysicalMemoryTypeFilter.getVMFlags](#)¹⁰⁹).

When the object is already mapped into virtual memory at a different address, this method remaps it to **base**.

When a remap is requested while another schedulable is accessing the raw memory, the map will block until one load or store completes. It can interrupt an array operation between entries.

Parameters

base The location to map at the virtual memory space.

size The size of the block to map in. When the size of the raw memory area is greater than **size**, the object is unchanged but accesses beyond the mapped region will throw [SizeOutOfBoundsException](#)¹¹⁰. When the size of the raw

¹⁰⁸Section [15.3.1.1.1](#)

¹⁰⁹Section [15.3.1.1.1](#)

¹¹⁰Section [14.3.2.14](#)

memory area is smaller than the mapped region access to the raw memory will behave as if the mapped region matched the raw memory area, but additional virtual address space will be consumed after the end of the raw memory area.

Throws

IllegalArgumentException when `size` is not greater than zero, `base` is not a legal value for a virtual address, or the memory-mapping hardware cannot place the physical memory at the designated address.

Returns

The starting point of the virtual memory.

setByte(long, byte)

Signature

```
public
void setByte(long offset,
              byte value)
```

Sets the **byte** at the given offset in the memory area associated with this object.

This memory access may involve a load and a store, and it may have unspecified effects on surrounding bytes in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See [Section **RawMemoryAccess.map\(long,long\)**](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area to which to write the byte.

value The byte to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException¹¹¹](#) somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the byte falls in an invalid address range.

¹¹¹Section [14.3.2.14](#)

SecurityException when this access is not permitted by the security manager.

setBytes(long, byte, int, int)

Signature

```
public
void setBytes(long offset,
               byte[] bytes,
               int low,
               int number)
```

Sets **number** bytes starting at the given offset in the memory area associated with this object from the byte array passed starting at position **low**.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See Section [RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area to which to start writing.

bytes The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹¹² somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the a short falls in an invalid address range. This is checked at every entry in the

¹¹²Section [14.3.2.14](#)

array to allow for the possibility that the memory area could be unmapped or remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

`ArrayIndexOutOfBoundsException` when `low` is less than 0 or greater than `bytes.length - 1`, or when `low + number` is greater than or equal to `bytes.length`.

`SecurityException` when this access is not permitted by the security manager.

setInt(long, int)

Signature

```
public
void setInt(long offset,
            int value)
```

Sets the `int` at the given offset in the memory area associated with this object. On most processor architectures an aligned integer can be stored in an atomic operation, but this is not required.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the `RawMemoryAccess` instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See [Section `RawMemoryAccess.map\(long,long\)`](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the integer.

value The integer to write.

Throws

`OffsetOutOfBoundsException` when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#)¹¹³ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

¹¹³Section [14.3.2.14](#)

SizeOutOfBoundsException when the object is not mapped, or when the integer falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

setInts(long, int, int, int)

Signature

```
public
void setInts(long offset,
             int[] ints,
             int low,
             int number)
```

Sets **number** ints starting at the given offset in the memory area associated with this object from the int array passed starting at position **low**. On most processor architectures each aligned integer can be stored in an atomic operation, but this is not required.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See Section [RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

ints The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹¹⁴

¹¹⁴Section [14.3.2.14](#)

somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when an int falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when `low` is less than 0 or greater than `bytes.length - 1`, or when `low + number` is greater than or equal to `bytes.length`.

SecurityException when this access is not permitted by the security manager.

setLong(long, long)

Signature

```
public
void setLong(long offset,
              long value)
```

Sets the **long** at the given offset in the memory area associated with this object. Even when it is aligned, the long value may not be updated atomically. It is unspecified how many load and store operations will be used or in what order.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See [Section RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the long.

value The long to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the

size of the raw memory area. The role of the [SizeOutOfBoundsException](#)¹¹⁵ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the long falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

setLongs(long, long, int, int)

Signature

```
public
void setLongs(long offset,
               long[] longs,
               int low,
               int number)
```

Sets **number** longs starting at the given offset in the memory area associated with this object from the long array passed starting at position **low**. Even when they are aligned, the long values may not be updated atomically. It is unspecified how many load and store operations will be used or in what order.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

[See Section RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

longs The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

¹¹⁵Section [14.3.2.14](#)

Throws

`OffsetOutOfBoundsException` when the offset is negative or greater than the size of the raw memory area. The role of the `SizeOutOfBoundsException`¹¹⁶ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

`SizeOutOfBoundsException` when the object is not mapped, or when the short falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

`ArrayIndexOutOfBoundsException` when `low` is less than 0 or greater than `bytes.length - 1`, or when `low + number` is greater than or equal to `bytes.length`.

`SecurityException` when this access is not permitted by the security manager.

setShort(long, short)*Signature*

```
public
void setShort(long offset,
               short value)
```

Sets the `short` at the given offset in the memory area associated with this object.

This memory access may involve a load and a store, and it may have unspecified effects on surrounding shorts in the presence of concurrent access.

Caching of the memory access is controlled by the memory `type` requested when the `RawMemoryAccess` instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See Section [RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the short.

value The short to write.

Throws

¹¹⁶Section [14.3.2.14](#)

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹¹⁷ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the short falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

setShorts(long, short, int, int)

Signature

```
public
void setShorts(long offset,
               short[] shorts,
               int low,
               int number)
```

Sets **number** shorts starting at the given offset in the memory area associated with this object from the short array passed starting at position **low**.

Each write of a short value may involve a load and a store, and it may have unspecified effects on surrounding shorts in the presence of concurrent access - even on other shorts in the array.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

See Section [RawMemoryAccess.map\(long,long\)](#)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

shorts The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

Throws

¹¹⁷Section [14.3.2.14](#)

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹¹⁸ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the a short falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when `low` is less than 0 or greater than `bytes.length - 1`, or when `low + number` is greater than or equal to `bytes.length`.

SecurityException when this access is not permitted by the security manager.

unmap

Signature

```
public  
void unmap()
```

Unmap the physical memory range from virtual memory. This changes the raw memory from the mapped state to the unmapped state. When the platform supports virtual memory, this operation frees the virtual addresses used for the raw memory region.

When the object is already in the unmapped state, this method has no effect.

While a raw memory object is unmapped all attempts to set or get values in the raw memory will throw **SizeOutOfBoundsException**¹¹⁹.

An unmapped raw memory object can be returned to mapped state with any of the object's `map` methods.

When an `unmap` is requested while another schedulable is accessing the raw memory, the `unmap` will throw an **IllegalStateException**. The `unmap` method can interrupt an array operation between entries.

15.3.3.10 RawMemoryFloatAccess

Inheritance

¹¹⁸Section 14.3.2.14

¹¹⁹Section 14.3.2.14

```

java.lang.Object
  javax.realtime.RawMemoryAccess
    javax.realtime.RawMemoryFloatAccess

```

This class holds the accessor methods for accessing a raw memory area by float and double types. Implementations are required to implement this class when and only when the underlying Java Virtual Machine supports floating point data types.

See [RawMemoryAccess](#)¹²⁰ for commentary on changes in the preferred use of this class following RTSJ 2.0.

By default, the byte addressed by `offset` is the byte at the lowest address of the floating point processor's floating point representation. When the type of memory used for this `RawMemoryFloatAccess` region implements a non-standard floating point format, accessor methods in this class continue to select bytes starting at `offset` from the base address and continuing toward greater addresses. The memory type may control the mapping of these bytes into the primitive data type. The memory type could even select bytes that are not contiguous. In each case the documentation for the [PhysicalMemoryTypeFilter](#)¹²¹ must document any mapping other than the "normal" one specified above.

All offset values used in this class are measured in bytes.

Atomic loads and stores on raw memory are defined in terms of physical memory. This memory may be accessible to threads outside the JVM and to non-programmed access (e.g., DMA), consequently atomic access must be supported by hardware. This specification is written with the assumption that all suitable hardware platforms support atomic loads for aligned floats. Atomic access beyond the specified minimum may be supported by the implementation.

Storing values into raw memory is more hardware-dependent than loading values. Many processor architectures do not support atomic stores of variables except for aligned stores of the processor's word size.

This class supports unaligned access to data, but it does not require the implementation to make such access atomic. Accesses to data aligned on its natural boundary will be atomic when the processor implements atomic loads and stores of that data size.

Except where noted, accesses to raw memory are not atomic with respect to the memory or with respect to threads. A raw memory area could be updated by another thread, or even unmapped in the middle of a method.

The characteristics of raw-memory access are necessarily platform dependent. This specification provides a minimum requirement for the RTSJ platform, but it also supports a optional system properties that identify a platform's level of support for atomic raw put and get. (See [RawMemoryAccess](#)¹²².) The properties represent

¹²⁰Section [15.3.3.9](#)

¹²¹Section [15.3.1.1](#)

¹²²Section [15.3.3.9](#)

a four-dimensional sparse array with boolean values whether that combination of access attributes is atomic. The default value for array entries is false.

Many of the constructors and methods in this class throw [OffsetOutOfBoundsException](#)¹²³. This exception means that the value given in the offset parameter is either negative or outside the memory area.

Many of the constructors and methods in this class throw [SizeOutOfBoundsException](#)¹²⁴. This exception means that the value given in the size parameter is either negative, larger than an allowable range, or would cause an accessor method to access an address outside of the memory area.

15.3.3.10.1 Constructors

RawMemoryFloatAccess(Object, long)

Signature

```
public
RawMemoryFloatAccess(Object type,
                      long size)
```

Construct an instance of `RawMemoryFloatAccess` with the given parameters, and set the object to the mapped state. When the platform supports virtual memory, map the raw memory into virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See [PhysicalMemoryTypeFilter.getVMAttributes](#)¹²⁵ and [PhysicalMemoryTypeFilter.getVMFlags](#)¹²⁶).

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type

¹²³Section [14.3.2.10](#)

¹²⁴Section [14.3.2.14](#)

¹²⁵Section [15.3.1.1.1](#)

¹²⁶Section [15.3.1.1.1](#)

of memory is acceptable. Note that `type` values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

Throws

SecurityException when the application doesn't have permissions to access physical memory, the specified range of addresses, or the given type of memory.

SizeOutOfBoundsException when the size is negative or extends into an invalid range of memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching [PhysicalMemoryTypeFilter](#)¹²⁷ has been registered with the [PhysicalMemoryManager](#)¹²⁸.

MemoryTypeConflictException when the specified base does not point to memory that matches the request type, or when `type` specifies incompatible memory attributes.

OutOfMemoryError when the requested type of memory exists, but there is not enough of it free to satisfy the request.

RawMemoryFloatAccess(Object, long, long)

Signature

```
public
RawMemoryFloatAccess(Object type,
                      long base,
                      long size)
```

Construct an instance of `RawMemoryFloatAccess` with the given parameters, and set the object to the mapped state. When the platform supports virtual memory, map the raw memory into virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See [PhysicalMemoryTypeFilter.getVMAttributes](#)¹²⁹ and [PhysicalMemoryTypeFilter.getVMFlags](#)¹³⁰).

¹²⁷Section [15.3.1.1](#)

¹²⁸Section [15.3.3.6](#)

¹²⁹Section [15.3.1.1.1](#)

¹³⁰Section [15.3.1.1.1](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the region.

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory, the specified range of addresses, or the given type of memory.

`OffsetOutOfBoundsException` when the address is invalid.

`SizeOutOfBoundsException` when the size is negative or extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹³¹ has been registered with the `PhysicalMemoryManager`¹³².

`MemoryTypeConflictException` when the specified base does not point to memory that matches the request type, or when **type** specifies incompatible memory attributes.

`OutOfMemoryError` when the requested type of memory exists, but there is not

15.3.3.10.2 Methods

getDouble(long)

Signature

```
public
double getDouble(long offset)
```

Gets the `double` at the given offset in the memory area associated with this object.

¹³¹Section 15.3.1.1

¹³²Section 15.3.3.6

The load is not required to be atomic even it is located on a natural boundary.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to load the long.

Throws

OffsetOutOfBoundsException when the offset is invalid.

SizeOutOfBoundsException when the object is not mapped, or when the double falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

Returns

The double from raw memory.

getDoubles(long, double, int, int)

Signature

```
public
void getDoubles(long offset,
                double[] doubles,
                int low,
                int number)
```

Gets **number** doubles starting at the given offset in the memory area associated with this object and assign them to the double array passed starting at position **low**.

The loads are not required to be atomic even when they are located on natural boundaries.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start loading.

doubles The array into which the loaded items are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

number The number of doubles to load.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See [RawMemoryAccess.map\(long, long\)](#)¹³³).

SizeOutOfBoundsException when the object is not mapped, or when a double falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **doubles** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

getFloat(long)

Signature

```
public  
float getFloat(long offset)
```

Gets the **float** at the given offset in the memory area associated with this object. When the float is aligned on a "natural" boundary it is always loaded from memory in a single atomic operation. When it is not on a natural boundary it may not be loaded atomically, and the number and order of the load operations is unspecified.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to load the float.

Throws

¹³³Section [15.3.3.9.2](#)

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See [RawMemoryAccess.map\(long, long\)](#)¹³⁴).

SizeOutOfBoundsException when the object is not mapped, or when the float falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

Returns

The float from raw memory.

getFloats(long, float, int, int)

Signature

```
public
void getFloats(long offset,
               float[] floats,
               int low,
               int number)
```

Gets **number** floats starting at the given offset in the memory area associated with this object and assign them to the int array passed starting at position **low**.

When the floats are aligned on natural boundaries each float is loaded from memory in a single atomic operation. Groups of floats may be loaded together, but this is unspecified.

When the floats are not aligned on natural boundaries they may not be loaded atomically and the number and order of load operations is unspecified.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start loading.

floats The array into which the floats loaded from the raw memory are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

¹³⁴Section [15.3.3.9.2](#)

number The number of floats to loaded.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See [RawMemoryAccess.map\(long, long\)](#)¹³⁵).

SizeOutOfBoundsException when the object is not mapped, or when a float falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **floats** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

setDouble(long, double)

Signature

```
public
void setDouble(long offset,
               double value)
```

Sets the **double** at the given offset in the memory area associated with this object. Even when it is aligned, the double value may not be updated atomically. It is unspecified how many load and store operations will be used or in what order.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the double.

value The double to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**

¹³⁵Section [15.3.3.9.2](#)

somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See [RawMemoryAccess.map\(long, long\)](#)¹³⁶).

SizeOutOfBoundsException when the object is not mapped, or when the double falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

setDoubles(long, double, int, int)

Signature

```
public
void setDoubles(long offset,
                double[] doubles,
                int low,
                int number)
```

Sets **number** doubles starting at the given offset in the memory area associated with this object from the double array passed starting at position **low**. Even when they are aligned, the double values may not be updated atomically. It is unspecified how many load and store operations will be used or in what order.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

doubles The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See [RawMemoryAccess.map\(long, long\)](#)¹³⁷).

¹³⁶Section [15.3.3.9.2](#)

¹³⁷Section [15.3.3.9.2](#)

SizeOutOfBoundsException when the object is not mapped, or when the a short falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **doubles** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

setFloat(long, float)

Signature

```
public
void setFloat(long offset,
              float value)
```

Sets the **float** at the given offset in the memory area associated with this object. On most processor architectures an aligned float can be stored in an atomic operation, but this is not required.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the integer.

value The float to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See [RawMemoryAccess.map\(long, long\)](#)¹³⁸).

SizeOutOfBoundsException when the object is not mapped, or when the float falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

¹³⁸Section [15.3.3.9.2](#)

setFloats(long, float, int, int)

Signature

```
public
void setFloats(long offset,
               float[] floats,
               int low,
               int number)
```

Sets **number** floats starting at the given offset in the memory area associated with this object from the float array passed starting at position **low**. On most processor architectures each aligned float can be stored in an atomic operation, but this is not required. Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

floats The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of floats to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See [RawMemoryAccess.map\(long, long\)](#)¹³⁹).

SizeOutOfBoundsException when the object is not mapped, or when the float falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

¹³⁹Section [15.3.3.9.2](#)

15.3.3.11 ScopedMemory

Inheritance

java.lang.Object
 javax.realtime.MemoryArea
 javax.realtime.ScopedMemory

ScopedMemory is the abstract base class of all classes dealing with representations of memory spaces which have a limited lifetime. In general, objects allocated in scoped memory are freed when (and only when) no schedulable object has access to the objects in the scoped memory.

A **ScopedMemory** area is a connection to a particular region of memory and reflects the current status of that memory. The object does not necessarily contain direct references to the region of memory. That is implementation dependent.

When a **ScopedMemory** area is instantiated, the object itself is allocated from the current memory allocation context, but the memory space that object represents (it's backing store) is allocated from memory that is not otherwise directly visible to Java code; e.g., it might be allocated with the C `malloc` function. This backing store behaves effectively as if it were allocated when the associated scoped memory object is constructed and freed at that scoped memory object's finalization.

The `ScopedMemory.enter`¹⁴⁰ method of **ScopedMemory** is one mechanism used to make a memory area the current allocation context. The other mechanism for activating a memory area is making it the initial memory area for a realtime thread or async event handler. Entry into the scope is accomplished, for example, by calling the

method:

```
public void enter(Runnable logic)
```

where `logic` is a instance of **Runnable** whose `run()` method represents the entry point of the code that will run in the new scope. Exit from the scope occurs between the time the `runnable.run()` method completes and the time control returns from the `enter` method. By default, allocations of objects within `runnable.run()` are taken from the backing store of the **ScopedMemory**.

ScopedMemory is an abstract class, but all specified methods include implementations. The responsibilities of **MemoryArea**, **ScopedMemory** and the classes that extend **ScopedMemory** are not specified. Application code should not extend **ScopedMemory** without detailed knowledge of its implementation.

15.3.3.11.1 Constructors

¹⁴⁰Section 15.3.3.11.2

ScopedMemory(long)

Signature

```
public  
ScopedMemory(long size)
```

Create a new `ScopedMemory` area with the given parameters.

Parameters

`size` of the new `ScopedMemory` area in bytes.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(long, Runnable)

Signature

```
public  
ScopedMemory(long size,  
              Runnable logic)
```

Create a new `ScopedMemory` area with the given parameters.

Parameters

`size` The size of the new `ScopedMemory` area in bytes.

`logic` The `Runnable` to execute when this `ScopedMemory` is entered. When `logic` is `null`, this constructor is equivalent to constructing the memory area without a logic value.

Throws

`IllegalArgumentException` when `size` is less than zero.

`IllegalAssignmentError` when storing `logic` in this would violate the assignment rules.

`OutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(SizeEstimator)

Signature

```
public  
ScopedMemory(SizeEstimator size)
```

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area estimated by an instance of `SizeEstimator`¹⁴¹.

Throws

`IllegalArgumentException` when **size** is null, or `size.getEstimate()` is negative.

`OutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(SizeEstimator, Runnable)

Signature

```
public  
ScopedMemory(SizeEstimator size,  
              Runnable logic)
```

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area estimated by an instance of `SizeEstimator`¹⁴².

logic The logic which will use the memory represented by `this` as its initial memory area. When **logic** is null, this constructor is equivalent to constructing the memory area without a logic value.

Throws

`IllegalArgumentException` when **size** is null, or `size.getEstimate()` is negative.

`OutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

`IllegalAssignmentError` when storing **logic** in `this` would violate the assignment rules.

¹⁴¹Section 11.4.2.5

¹⁴²Section 11.4.2.5

15.3.3.11.2 Methods

enter

Signature

```
public  
void enter()
```

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the instance of `Runnable` given in the constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`¹⁴³) or the `enter` method exits.

Throws

`ScopedCycleException` when this invocation would break the single parent rule.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`¹⁴⁴, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹⁴⁵ is allocated in the current allocation context and contains information about the exception it replaces.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`IllegalArgumentException`

`MemoryAccessError`

enter(Runnable)

Signature

¹⁴³Section 15.3.3.11.2

¹⁴⁴Section 14.3.3.3

¹⁴⁵Section 14.3.3.7

```
public
void enter(Runnable logic)
```

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the given `Runnable`. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`¹⁴⁶) or the `enter` method exits.

Parameters

`logic`

Throws

`ScopedCycleException` when this invocation would break the single parent rule.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`¹⁴⁷, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹⁴⁸ is allocated in the current allocation context and contains information about the exception it replaces.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`IllegalArgumentException`

executeInArea(Runnable)

Signature

```
public
void executeInArea(Runnable logic)
```

Execute the run method from the `logic` parameter using this memory area as the current allocation context. This method behaves as if it moves the allocation context down the scope stack to the occurrence of `this`.

Parameters

`logic` The runnable object whose `run()` method should be executed.

¹⁴⁶Section [15.3.3.11.2](#)

¹⁴⁷Section [14.3.3.3](#)

¹⁴⁸Section [14.3.3.7](#)

Throws

`IllegalThreadStateException` when the caller is a Java thread.

`InaccessibleAreaException` when the memory area is not in the schedulable's scope stack.

`IllegalArgumentException` when the caller is a schedulable and `logic` is `null`.

getPortal

Signature

```
public  
java.lang.Object getPortal()
```

Return a reference to the portal object in this instance of `ScopedMemory`.

Assignment rules are enforced on the value returned by `getPortal` as if the return value were first stored in an object allocated in the current allocation context, then moved to its final destination.

Throws

`IllegalAssignmentError` when a reference to the portal object cannot be stored in the caller's allocation context; that is, when `this` is "inner" relative to the current allocation context or not on the caller's scope stack.

`IllegalThreadStateException` when the caller is a Java thread.

Returns

A reference to the portal object or `null` when there is no portal object. The portal value is always set to `null` when the contents of the memory are deleted.

getReferenceCount

Signature

```
public  
int getReferenceCount()
```

Returns the reference count of this `ScopedMemory`.

Note: A reference count of 0 reliably means that the scope is not referenced, but other reference counts are subject to artifacts of lazy/eager maintenance by the implementation.

Returns

The reference count of this `ScopedMemory`.

join

Signature

```
public
void join()
throws InterruptedException
```

Wait until the reference count of this `ScopedMemory` goes down to zero. Return immediately when the memory is unreferenced.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁴⁹ or `AsynchronouslyInterruptedException.fire()`¹⁵⁰ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread.

join(HighResolutionTime)

Signature

```
public
void join(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException
```

Wait at most until the time designated by the `time` parameter for the reference count of this `ScopedMemory` to drop to zero. Return immediately when the memory area is unreferenced.

Since the time is expressed as a `HighResolutionTime`¹⁵¹, this method is an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the delay is the amount of time given by `time`, and measured by its associated clock. When absolute, then the delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `join` returns immediately.

Parameters

time When this time is an absolute time, the wait is bounded by that point in time. When the time is a relative time (or a member of the `RationalTime` subclass of `RelativeTime`) the wait is bounded by a the specified interval from

¹⁴⁹Section 5.3.2.2.2

¹⁵⁰Section 8.4.2.1.2

¹⁵¹Section 9.4.1.2

some time between the time `join` is called and the time it starts waiting for the reference count to reach zero.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁵² or `AsynchronouslyInterruptedException.fire()`¹⁵³ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread.

`IllegalArgumentException` when the caller is a schedulable and `time` is null.

`UnsupportedOperationException` when the wait operation is not supported using the clock associated with `time`.

joinAndEnter

Signature

```
public
void joinAndEnter()
throws InterruptedException
```

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, then enter the `ScopedMemory` and execute the `run` method from `logic` passed in the constructor. When no instance of `Runnable` was passed to the memory area's constructor, the method throws `IllegalArgumentException` immediately.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although `joinAndEnter` guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference count will remain one for any length of time. A subsequent `enter` could raise the reference count to two.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁵⁴ or `AsynchronouslyInterruptedException.fire()`¹⁵⁵ while waiting for the reference count to go to zero.

¹⁵²Section 5.3.2.2.2

¹⁵³Section 8.4.2.1.2

¹⁵⁴Section 5.3.2.2.2

¹⁵⁵Section 8.4.2.1.2

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in **this** scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an **IllegalAssignmentError**¹⁵⁶, so the JVM cannot be permitted to deliver the exception. The **ThrowBoundaryError**¹⁵⁷ is allocated in the current allocation context and contains information about the exception it replaces.

ScopedCycleException when this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable and no non-null logic value was supplied to the memory area's constructor.

MemoryAccessError when caller is a non-heap schedulable and this memory area's logic value is allocated in heap memory.

joinAndEnter(HighResolutionTime)

Signature

```
public
void joinAndEnter(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException
```

In the error-free case, **joinAndEnter** combines **join();enter();** such that no **enter()** from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this **ScopedMemory** to reach zero, or for the current time to reach the designated time, then enter the **ScopedMemory** and execute the **run** method from **Runnable** object passed to the constructor. When no instance of **Runnable** was passed to the memory area's constructor, the method throws **IllegalArgumentException** immediately. *

When multiple threads are waiting in **joinAndEnter** family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Since the time is expressed as a **HighResolutionTime**¹⁵⁸, this method has an

¹⁵⁶Section 14.3.3.3

¹⁵⁷Section 14.3.3.7

¹⁵⁸Section 9.4.1.2

accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the calling thread is blocked for at most the amount of time given by `time`, and measured by its associated clock. When absolute, then the time delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `joinAndEnter` behaves effectively like `enter`¹⁵⁹.

Note that expiration of `time` may cause control to enter the memory area before its reference count has gone to zero.

Parameters

`time` The time that bounds the wait.

Throws

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an **IllegalAssignmentError**¹⁶⁰, so the JVM cannot be permitted to deliver the exception. The **ThrowBoundaryError**¹⁶¹ is allocated in the current allocation context and contains information about the exception it replaces.

InterruptedException When this schedulable is interrupted by **RealtimeThread.interrupt()**¹⁶² or **AsynchronouslyInterruptedException.fire()**¹⁶³ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

ScopedCycleException when the caller is a schedulable and this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable, and `time` is `null` or no non-null logic value was supplied to the memory area's constructor.

UnsupportedOperationException when the wait operation is not supported using the clock associated with `time`.

MemoryAccessError when caller is a no-heap schedulable and this memory area's logic value is allocated in heap memory.

¹⁵⁹Section 15.3.3.11.2

¹⁶⁰Section 14.3.3.3

¹⁶¹Section 14.3.3.7

¹⁶²Section 5.3.2.2.2

¹⁶³Section 8.4.2.1.2

joinAndEnter(Runnable)

Signature

```
public  
void joinAndEnter(Runnable logic)  
throws InterruptedException
```

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, then enter the `ScopedMemory` and execute the `run` method from `logic`.

When `logic` is `null`, throw `IllegalArgumentException` immediately.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although `joinAndEnter` guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference count will remain one for any length of time. A subsequent `enter` could raise the reference count to two.

Parameters

`logic` The `Runnable` object which contains the code to execute.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁶⁴ or `AsynchronouslyInterruptedException.fire()`¹⁶⁵ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in *this* scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`¹⁶⁶, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹⁶⁷ is allocated in the current allocation context and contains information about the exception it replaces.

¹⁶⁴Section 5.3.2.2.2

¹⁶⁵Section 8.4.2.1.2

¹⁶⁶Section 14.3.3.3

¹⁶⁷Section 14.3.3.7

`ScopedCycleException` when this invocation would break the single parent rule.

`IllegalArgumentException` when the caller is a schedulable and `logic` is `null`.

joinAndEnter(Runnable, HighResolutionTime)

Signature

```
public
void joinAndEnter(Runnable logic,
                  javafx.realtime.HighResolutionTime<?> time)
throws InterruptedException
```

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, or for the current time to reach the designated time, then enter the `ScopedMemory` and execute the `run` method from `logic`.

Since the time is expressed as a `HighResolutionTime`¹⁶⁸, this method is an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the delay is the amount of time given by `time`, and measured by its associated clock. When absolute, then the delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `joinAndEnter` behaves effectively like `enter(Runnable)`¹⁶⁹.

Throws `IllegalArgumentException` immediately when `logic` is `null`.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that expiration of `time` may cause control to enter the memory area before its reference count has gone to zero.

Parameters

logic The `Runnable` object which contains the code to execute.

time The time that bounds the wait.

Throws

¹⁶⁸Section 9.4.1.2

¹⁶⁹Section 15.3.3.11.2

InterruptedException When this schedulable is interrupted by [RealtimeThread.interrupt\(\)](#)¹⁷⁰ or [AsynchronouslyInterruptedException.fire\(\)](#)¹⁷¹ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in **this** scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an [IllegalAssignmentError](#)¹⁷², so the JVM cannot be permitted to deliver the exception. The [ThrowBoundaryError](#)¹⁷³ is allocated in the current allocation context and contains information about the exception it replaces.

ScopedCycleException when the caller is a schedulable and this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable and **time** or **logic** is **null**.

UnsupportedOperationException when the wait operation is not supported using the clock associated with **time**.

newArray(Class, int)

Signature

```
public
java.lang.Object newArray(java.lang.Class<?> type,
                           int number)
```

Allocate an array of the given type in this memory area. This method may be concurrently used by multiple threads.

Parameters

type
number

Throws

IllegalArgumentException

¹⁷⁰Section [5.3.2.2.2](#)

¹⁷¹Section [8.4.2.1.2](#)

¹⁷²Section [14.3.3.3](#)

¹⁷³Section [14.3.3.7](#)

OutOfMemoryError

IllegalThreadStateException when the caller is a Java thread.

InaccessibleAreaException when the memory area is not in the schedulable's scope stack.

Returns

newInstance(Class)

Signature

```
public
T newInstance(java.lang.Class< T> type)
throws IllegalAccessException,
    InstantiationException
```

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

type

Throws

IllegalAccessException

IllegalArgumentException

ExceptionInInitializerError

OutOfMemoryError

InstantiationException

IllegalThreadStateException when the caller is a Java thread.

InaccessibleAreaException when the memory area is not in the schedulable's scope stack.

Returns

newInstance(Constructor, Object)

Signature

```
public
T newInstance(java.lang.reflect.Constructor< T> c,
    java.lang.Object[] args)
```

```
throws IllegalAccessException,  
        InstantiationException,  
        InvocationTargetException
```

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

```
c T  
args
```

Throws

```
IllegalAccessException  
InstantiationException  
OutOfMemoryError  
IllegalArgumentException  
IllegalThreadStateException when the caller is a Java thread.  
InvocationTargetException  
InaccessibleAreaException when the memory area is not in the schedul-  
able's scope stack.
```

Returns

setPortal(Object)

Signature

```
public  
void setPortal(Object object)
```

Sets the *portal* object of the memory area represented by this instance of **ScopedMemory** to the given object. The object must have been allocated in this **ScopedMemory** instance.

Parameters

object The object which will become the portal for this. When **null** the previous portal object remains the portal object for this or when there was no previous portal object then there is still no portal object for **this**.

Throws

```
IllegalThreadStateException when the caller is a Java Thread.  
IllegalAssignmentError when the caller is a schedulable, and object is not  
allocated in this scoped memory instance and not null.
```

InaccessibleAreaException when the caller is a schedulable, **this** memory area is not in the caller's scope stack and **object** is not **null**.

toString

Signature

```
public
java.lang.String toString()
```

Returns a user-friendly representation of this **ScopedMemory** of the form **ScopedMemory#<num>** where **<num>** is a number that uniquely identifies this scoped memory area.

Returns

The string representation

15.3.3.12 VTMemory

Inheritance

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.ScopedMemory
      javax.realtime.VTMemory
```

VTMemory is similar to **LTMemory**¹⁷⁴ except that the execution time of an allocation from a **VTMemory** area need not complete in linear time.

Methods from **VTMemory** should be overridden only by methods that use **super**.

15.3.3.12.1 Constructors

VTMemory(long, long)

Signature

```
public
VTMemory(long initial,
          long maximum)
```

¹⁷⁴Section [15.3.3.2](#)

Creates a `VTMemory` with the given parameters.

Parameters

initial The size in bytes of the memory to initially allocate for this area.

maximum The maximum size in bytes this memory area to which the size may grow.

Throws

`IllegalArgumentException` when **initial** is greater than **maximum** or when **initial** or **maximum** is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

`VTMemory(long, long, Runnable)`

Signature

```
public
VTMemory(long initial,
         long maximum,
         Runnable logic)
```

Creates a `VTMemory` with the given parameters.

Parameters

initial The size in bytes of the memory to initially allocate for this area.

maximum The maximum size in bytes this memory area to which the size may grow.

logic An instance of `Runnable` whose `run()` method will use `this` as its initial memory area. When **logic** is `null`, this constructor is equivalent to `VTMemory(long initial, long maximum)`¹⁷⁵.

Throws

`IllegalArgumentException` when **initial** is greater than **maximum**, or when **initial** or **maximum** is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing **logic** in `this` would violate the assignment rules.

¹⁷⁵Section [15.3.3.12.1](#)

VTMemory(SizeEstimator, SizeEstimator)

Signature

```
public
VTMemory(SizeEstimator initial,
          SizeEstimator maximum)
```

Creates a VTMemory with the given parameters.

Parameters

initial The size in bytes of the memory to initially allocate for this area.
maximum The maximum size in bytes this memory area to which the size may grow estimated by an instance of [SizeEstimator](#)¹⁷⁶.

Throws

IllegalArgumentException when **initial** is null, **maximum** is null, **initial.getEstimate()** is greater than **maximum.getEstimate()**, or when **initial.getEstimate()** is less than zero.
OutOfMemoryError when there is insufficient memory for the VTMemory object or for the backing memory.

VTMemory(SizeEstimator, SizeEstimator, Runnable)

Signature

```
public
VTMemory(SizeEstimator initial,
          SizeEstimator maximum,
          Runnable logic)
```

Creates a VTMemory with the given parameters.

Parameters

initial The size in bytes of the memory to initially allocate for this area.
maximum The maximum size in bytes this memory area to which the size may grow estimated by an instance of [SizeEstimator](#)¹⁷⁷.
logic An instance of **Runnable** whose **run()** method will use **this** as its initial memory area. When **logic** is null, this constructor is equivalent to

¹⁷⁶Section [11.4.2.5](#)

¹⁷⁷Section [11.4.2.5](#)

`VTMemory(SizeEstimator initial, SizeEstimator maximum)`¹⁷⁸.

Throws

`IllegalArgumentException` when `initial` is null, `maximum` is null, `initial.getEstimate()` is greater than `maximum.getEstimate()`, or when `initial.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing logic in `this` would violate the assignment rules.

VTMemory(long)

Signature

```
public
VTMemory(long size)
```

Create an `VTMemory` of the given size. This constructor is equivalent to `VTMemory(size, size)`

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

VTMemory(long, Runnable)

Signature

```
public
VTMemory(long size,
          Runnable logic)
```

Create an `VTMemory` of the given size. This constructor is equivalent to `VTMemory(size, size, logic)`.

Parameters

¹⁷⁸Section [15.3.3.12.1](#)

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

logic The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is null, this constructor is equivalent to `VTMemory(long size)`¹⁷⁹.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

VTMemory(SizeEstimator)

Signature

```
public  
VTMemory(SizeEstimator size)
```

Create an `VTMemory` of the given size. This constructor is equivalent to `VTMemory(size, size)`.

Parameters

size An instance of `SizeEstimator`¹⁸⁰ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

VTMemory(SizeEstimator, Runnable)

Signature

```
public  
VTMemory(SizeEstimator size,
```

¹⁷⁹Section 15.3.3.12.1

¹⁸⁰Section 11.4.2.5

Runnable logic)

Create an `VTMemory` of the given size.

Parameters

size An instance of `SizeEstimator`¹⁸¹ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

logic The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `VTMemory(SizeEstimator initial)`¹⁸².

Throws

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

15.3.3.12.2 Methods

toString

Signature

```
public  
java.lang.String toString()
```

Create a string representing this object. The string is of the form `(VTMemory) Scoped memory # num` where `num` uniquely identifies the `VTMemory` area.

Returns

A string representing the value of `this`.

15.3.3.13 VTPhysicalMemory

¹⁸¹Section 11.4.2.5

¹⁸²Section 15.3.3.12.1

Inheritance

java.lang.Object
 [javax.realtime.MemoryArea](#)
 [javax.realtime.ScopedMemory](#)
 [javax.realtime.VTPhysicalMemory](#)

An instance of `VTPhysicalMemory` allows objects to be allocated from a range of physical memory with particular attributes, determined by their memory type. This memory area has the same semantics as [ScopedMemory](#)¹⁸³ memory areas, and the same performance restrictions as `VTMemory`.

No provision is made for sharing object in `VTPhysicalMemory` with entities outside the JVM that creates them, and, while the memory backing an instance of `VTPhysicalMemory` could be shared by multiple JVMs, the class does not support such sharing.

Methods from `VTPhysicalMemory` should be overridden only by methods that use `super`.

[See Section MemoryArea](#)

[See Section ScopedMemory](#)

[See Section VTMemory](#)

[See Section LTMemory](#)

[See Section LTPhysicalMemory](#)

[See Section ImmortalPhysicalMemory](#)

[See Section RealtimeThread](#)

[See Section NoHeapRealtimeThread](#)

15.3.3.13.1 Constructors

VTPhysicalMemory(Object, long)

¹⁸³Section [15.3.3.11](#)

Signature

```
public
VTPhysicalMemory(Object type,
                  long size)
```

Create an instance of `VTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that **size** extends beyond physically addressable memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching [PhysicalMemoryTypeFilter](#)¹⁸⁴ has been registered with the [PhysicalMemoryManager](#)¹⁸⁵.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`IllegalArgumentException` when **size** is less than zero.

VTPhysicalMemory(Object, long, long)

Signature

```
public
VTPhysicalMemory(Object type,
                  long base,
                  long size)
```

¹⁸⁴Section [15.3.1.1](#)

¹⁸⁵Section [15.3.3.6](#)

Create an instance of `VTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that **size** extends beyond physically addressable memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching [PhysicalMemoryTypeFilter](#)¹⁸⁶ has been registered with the [PhysicalMemoryManager](#)¹⁸⁷.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`MemoryInUseException` when the specified memory is already in use.

VTPhysicalMemory(Object, SizeEstimator)

Signature

```
public
VTPhysicalMemory(Object type,
                  SizeEstimator size)
```

Create an instance of `VTPhysicalMemory` with the given parameters.

¹⁸⁶Section [15.3.1.1](#)

¹⁸⁷Section [15.3.3.6](#)

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size A size estimator for this area.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that the size estimate from **size** extends beyond physically addressable memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching [PhysicalMemoryTypeFilter](#)¹⁸⁸ has been registered with the [PhysicalMemoryManager](#)¹⁸⁹.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`IllegalArgumentException` when **size** is `null`, or `size.getEstimate()` is negative.

VTPhysicalMemory(Object, long, SizeEstimator)

Signature

```
public
VTPhysicalMemory(Object type,
                  long base,
                  SizeEstimator size)
```

Create an instance of `VTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

¹⁸⁸Section [15.3.1.1](#)

¹⁸⁹Section [15.3.3.6](#)

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that the size estimate from **size** extends beyond physically addressable memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁹⁰ has been registered with the `PhysicalMemoryManager`¹⁹¹.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`MemoryInUseException` when the specified memory is already in use.

`IllegalArgumentException` when **size** is `null`, or `size.getEstimate()` is negative.

VTPhysicalMemory(Object, long, Runnable)

Signature

```
public
VTPhysicalMemory(Object type,
                  long size,
                  Runnable logic)
```

Create an instance of `VTPhysicalMemory` with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

¹⁹⁰Section [15.3.1.1](#)

¹⁹¹Section [15.3.3.6](#)

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`¹⁹² is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that **size** extends beyond physically addressable memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁹³ has been registered with the `PhysicalMemoryManager`¹⁹⁴.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`IllegalAssignmentError` when storing **logic** in **this** would violate the assignment rules.

VTPhysicalMemory(Object, long, long, Runnable)

Signature

```
public
VTPhysicalMemory(Object type,
                  long base,
                  long size,
                  Runnable logic)
```

Create an instance of `VTPhysicalMemory` with the given parameters.

¹⁹²Section [11.4.2.3.2](#)

¹⁹³Section [15.3.1.1](#)

¹⁹⁴Section [15.3.3.6](#)

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size The size of the area in bytes.

logic The `run()` method of this object will be called whenever [MemoryArea.enter\(\)](#)¹⁹⁵ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SizeOutOfBoundsException` when the implementation detects that **size** extends beyond physically addressable memory.

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching [PhysicalMemoryTypeFilter](#)¹⁹⁶ has been registered with the [PhysicalMemoryManager](#)¹⁹⁷.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`MemoryInUseException` when the specified memory is already in use.

`IllegalAssignmentError` when storing **logic** in **this** would violate the assignment rules.

VTPhysicalMemory(Object, SizeEstimator, Runnable)

Signature

`public`

¹⁹⁵Section [11.4.2.3.2](#)

¹⁹⁶Section [15.3.1.1](#)

¹⁹⁷Section [15.3.3.6](#)

```
VTPhysicalMemory(Object type,  
                  SizeEstimator size,  
                  Runnable logic)
```

Create an instance of `VTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size A size estimator for this area.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`¹⁹⁸ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that the size estimate from **size** extends beyond physically addressable memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁹⁹ has been registered with the `PhysicalMemoryManager`²⁰⁰.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`IllegalArgumentException` when **size** is `null`, or `size.getEstimate()` is negative.

`IllegalAssignmentError` when storing **logic** in **this** would violate the assignment rules.

VTPhysicalMemory(Object, long, SizeEstimator, Runnable)

¹⁹⁸Section [11.4.2.3.2](#)

¹⁹⁹Section [15.3.1.1](#)

²⁰⁰Section [15.3.3.6](#)

Signature

```
public
VTPhysicalMemory(Object type,
                  long base,
                  SizeEstimator size,
                  Runnable logic)
```

Create an instance of `VTPhysicalMemory` with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`²⁰¹ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that the size estimate from **size** extends beyond physically addressable memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`²⁰² has been registered with the `PhysicalMemoryManager`²⁰³.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

²⁰¹Section [11.4.2.3.2](#)

²⁰²Section [15.3.1.1](#)

²⁰³Section [15.3.3.6](#)

`MemoryInUseException` when the specified memory is already in use.

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is negative.

`IllegalAssignmentError` when storing logic in this would violate the assignment rules.

15.3.3.13.2 Methods

toString

Signature

```
public  
java.lang.String toString()
```

Creates a string representing this object. The string is of the form (VTPhysicalMemory) Scoped memory # num where num is a number that uniquely identifies this VTPhysicalMemory memory area.

Returns

A string representing the value of `this`.

15.3.3.14 WaitFreeDequeue

Inheritance

```
java.lang.Object  
  javax.realtime.WaitFreeDequeue
```

A `WaitFreeDequeue` encapsulates a `WaitFreeWriteQueue` and a `WaitFreeReadQueue`. Each method on a `WaitFreeDequeue` corresponds to an equivalent operation on the underlying `WaitFreeWriteQueue` or `WaitFreeReadQueue`.

Incompatibility with V1.0: Three exceptions previously thrown by the constructor have been deleted from the `throws` clause. These are:

- `java.lang.IllegalAccessException`,
- `java.lang.ClassNotFoundException`, and
- `java.lang.InstantiationException`.

Including these exceptions on the `throws` clause was an error. Their deletion may cause compile-time errors in code using the previous constructor. The repair is to remove the exceptions from the `catch` clause around the constructor invocation.

`WaitFreeDequeue` is one of the classes allowing `NoHeapRealtimeThreads` and regular Java threads to synchronize on an object without the risk of a `NoHeapRealtimeThread` incurring Garbage Collector latency due to priority inversion avoidance management.

15.4 Rationale

These are interface that have been shown to be less the ideal. They have been replaced by classes that better fulfill the requirements. Compatibility can be provided by implemenations that use existing facilities so there is not reason to continue requiring their inclusion new implementations.

Chapter 16

Conformance, Compliance, and Portability

16.1 Overview

There are many applications that can benefit from the API and semantic refinements of the Java runtime environment that have been described above. Not every application requires all parts, so some flexibility of implementation is necessary. Therefore the RTSJ is divided into a core package and two optional packages. Furthermore, it also provides for different usage modes to support both development and deployment.

16.2 Semantics

The definition of the RTSJ indicates that implementations may provide different semantics for scheduling, synchronization, and garbage collection. This section defines what minimum semantics for these areas and other semantics and APIs required of all implementations of the RTSJ. Other than what is described in the optional modules or explicitly noted as optionally required, the RTSJ does not allow any subsetting of the APIs in the `javax.realtime` package; however, some of the classes are specific to certain well-known scheduling or synchronization algorithms and may have no underlying support in a minimum implementation of the RTSJ. The RTSJ provides these classes as standard parent classes for implementations supporting such algorithms.

16.2.1 Modules

As described in Section 3.2, the RTSJ now has modules. Every implementation, except one supporting **Safety Critical Java**, must implement the Core module. In addition, a realtime deployment implementation must have a realtime garbage collector or implement the alternate memory area module. Each module provided by an implementation must be provided in full. None of the classes of an unimplemented module should be present. An implementation of this specification for **Safety Critical Java**, must implement the methods and classes defined in that specification.

16.2.2 Optionally Required Components

The RTSJ does not, in general, support the concept of optional components of the specification. Optional components would further complicate the already difficult task of writing WORA (Write Once Run Anywhere) software components for real-time systems. However, understanding the difficulty of providing implementations of mechanisms for which there is no underlying support, the RTSJ does provide for a few exceptions. Any components that are considered optional will be listed as such in the class definitions.

The most notable optional component of the specification is **POSIXSignal**. A conformant implementation which implements the Device module must support POSIX signals on underlying system that support the underlying system supports them.

16.2.3 Deployment Implementation

The minimum scheduling semantics that must be supported in all implementations of the RTSJ are fixed-priority preemptive scheduling and at least 28 unique priority levels. By fixed-priority we mean that the system does not change the priority of any **RealtimeThread** or **NoHeapRealtimeThread** except, temporarily, for priority inversion avoidance. Note, however, that application code may change such priorities. What the RTSJ precludes by this statement is scheduling algorithms that change thread priorities according to policies for optimizing throughput (such as increasing the priority of threads that have been receiving few processor cycles because of higher priority threads (aging)). The 28 unique priority levels are required to be unique to preclude implementations from using fewer priority levels of underlying systems to implement the required 28 by simplistic algorithms (such as lumping four RTSJ priorities into seven buckets for an underlying system that only supports seven priority levels). It is sufficient for systems with fewer than 28 priority levels to use more sophisticated algorithms to implement the required 28 unique levels as long as **RealtimeThreads** and **NoHeapRealtimeThreads** behave as though there were at

least 28 unique levels. (e.g. if there were 28 RealtimeThreads (t_1, \dots, t_{28}) with priorities (p_1, \dots, p_{28}), respectively, where the value of p_1 was the highest priority and the value of p_2 the next highest priority, etc., then for all executions of threads t_1 through t_{28} thread t_1 would *always* execute in preference to threads t_2, \dots, t_{28} and thread t_2 would *always* execute in preference to threads t_3, \dots, t_{28} , etc.)

The minimum synchronization semantics that must be supported in all deployment implementations of the RTSJ are detailed in the above section on synchronization and repeated here.

All deployment implementations of the RTSJ must provide an implementation of the synchronized primitive with default behavior that ensures that there is no unbounded priority inversion. Furthermore, this must apply to code if it is run within the implementation as well as to realtime threads. The priority inheritance protocol must be implemented by default.

All threads waiting to acquire a resource must be queued in priority order. This applies to the processor as well as to synchronized blocks. When threads with the same exact priority are possible under the active scheduling policy, threads with the same priority are queued in FIFO order. (Note that these requirements apply only to the required base scheduling policy and hence use the specific term "priority"). In particular,

- threads waiting to enter synchronized blocks are granted access to the synchronized block in priority order;
- a blocked thread that becomes ready to run is given access to the processor in priority order;
- a thread whose execution eligibility is explicitly set by itself or another thread is given access to the processor in priority order;
- a thread that performs a `yield()` will be given access to the processor after waiting threads of the same priority;
- however, threads that are preempted in favor of a thread with higher priority may be given access to the processor at any time as determined by a particular implementation. The implementation is required to provide documentation stating exactly the algorithm used for granting such access.

The RTSJ does not require any particular garbage collection algorithm; however, every deployment implementation must either implement the alternate memory area module or have a realtime garbage collection. In the later case, the realtime limitations must be documented. All implementations of the RTSJ must support the class `GarbageCollector` and implement all of its methods.

Notwithstanding the above, a program that uses the RTSJ and is deployed as an executable, so that it does not provide general access to the virtual machine, but solely runs that program code, need only include the `rtsj` methods and classes needed by the application.

16.2.4 Simulation Implementation

An implementation that chooses not to provide realtime guarantees, is termed a simulation implementation. Such an implementation does not need to provide the realtime characteristic described above, but does need to at least provide all the APIs of the core module. A simulation implementation can be a production system, but not for realtime applications. This enables a conventional JVM to make the base APIs available to a wider audience without changing its performance characteristics.

16.2.5 Documentation Requirements

In order to properly engineer a realtime system, an understanding of the cost associated with any arbitrary code segment is required. This is especially important for operations that are performed by the runtime system, largely hidden from the programmer. (An example of this is the maximum expected latency before the garbage collector can be interrupted.)

The RTSJ does not require specific performance or latency numbers to be matched. Rather, to be conformant to this specification, an implementation must provide documentation regarding the expected behavior of particular mechanisms. The mechanisms requiring such documentation, and the specific data to be provided, will be detailed in the class and method definitions.

16.3 Rationale

The embedded market, especially for safety critical applications, is quite sensitive to including code that is not needed by an application. Furthermore, different application domains have differing needs on API. Flexibility is needed to ensure that these diverse domains and requirements are met. Still, it is important to ensure that when a given function is needed, it is included as defined herein. It is also important that an open virtual machine deployment has a well-defined API set. The above modules and deployment rules provide both this flexibility and standardization.

Appendix A

Bibliography

- [1] *Portable Operating System Interface (POSIX[®]) Part 1: System Application Program Interface, International Standard ISO/IEC 9945-1, 1996 (E) IEEE Std 1003.1*, 1996 edition ed. The Institute of Electrical and Electronics Engineers, Inc., 1996.
- [2] BARR, M. Memory types. *Embedded Systems Programming* (2001), 103–104.
- [3] BURNS, A., AND WELLINGS, A. J. *Real-Time Systems and Programming Languages*; 4th ed. Addison Wesley, 2010.
- [4] DOS SANTOS, O. M., AND WELLINGS, A. Cost enforcement in the real-time specification for java. *Real-Time Syst.* 37, 2 (Nov. 2007), 139–179.
- [5] GOSLING, J., JOY, B., STEELE, G., BRACHA, G., AND BUCKLEY, A. *The Java Language Specification Java SE 8 Edition*. Oracle, 2014.
- [6] LINDHOLM, T., YELLIN, F., BRACHA, G., AND BUCKLEY, A. *The Java Virtual Machine Specification Java SE 8 Edition*. Oracle, 2014.
- [7] REGEHR, J. Safe and structured use of interrupts in real-time and embedded software. In *Handbook of Real-Time and Embedded Systems*, I. Lee, J. Y.-T. Leug, and S. H. Son, Eds. Chapman and Hall/CRC, 2007, pp. 16–1–16–12.

