Overview of Java Synchronizer Classes

Douglas C. Schmidt
d.schmidt@vanderbilt.edu
www.dre.vanderbilt.edu/~schmidt

Institute for Software
Integrated Systems
Vanderbilt University
Nashville, Tennessee, USA

Learning Objectives in this Lesson

- Know the key synchronizers defined in the Java class library

Java Class	Purpose
ReentrantLock	A reentrant mutual exclusion lock that extends the built-in monitor lock capabilities
ReentrantReadWriteLock	Improves performance when resources are read much more often than written
StampedLock	A readers-writer lock that's more efficient than ReentrantReadWriteLock
Semaphore	Maintains permits that controls thread access to limited # of shared resources
ConditionObject	Allows Thread to block until a condition becomes true
CountDownLatch	Allows one or more threads to wait until a set of operations being performed in other threads complete
CyclicBarrier	Allows a set of threads to all wait for each other to reach a common barrier point
Phaser	A more flexible reusable synchronization barrier

Learning Objectives in this Lesson

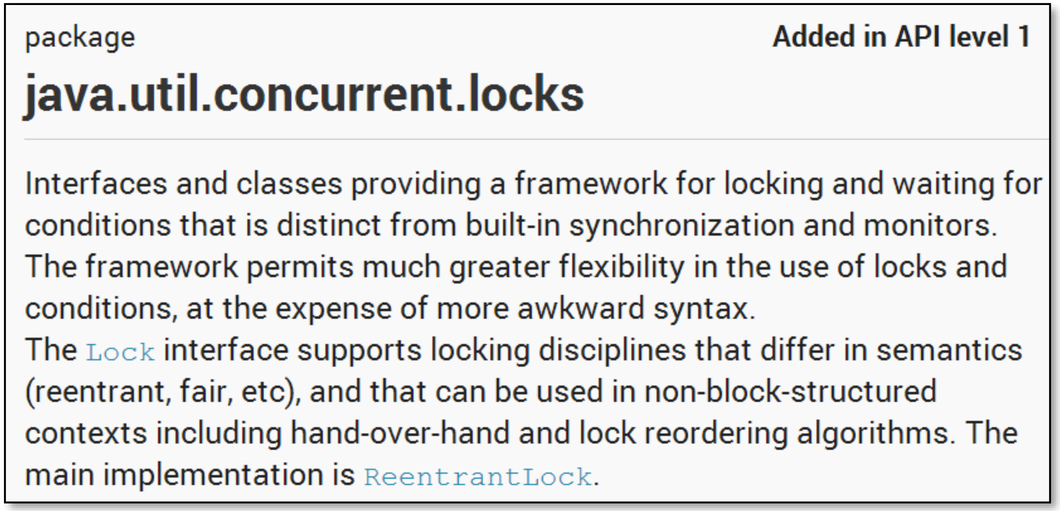
- Know the key synchronizers defined in the Java class library
- Recognize synchronizer usage considerations

Performance
Productivity

Overview of Java Synchronizer Classes

Overview of Java Synchronizer Classes

- The java.util.concurrent & java.util.concurrent.locks packages define *many* synchronizers
  - e.g., java.util.concurrent & java.util.concurrent.locks



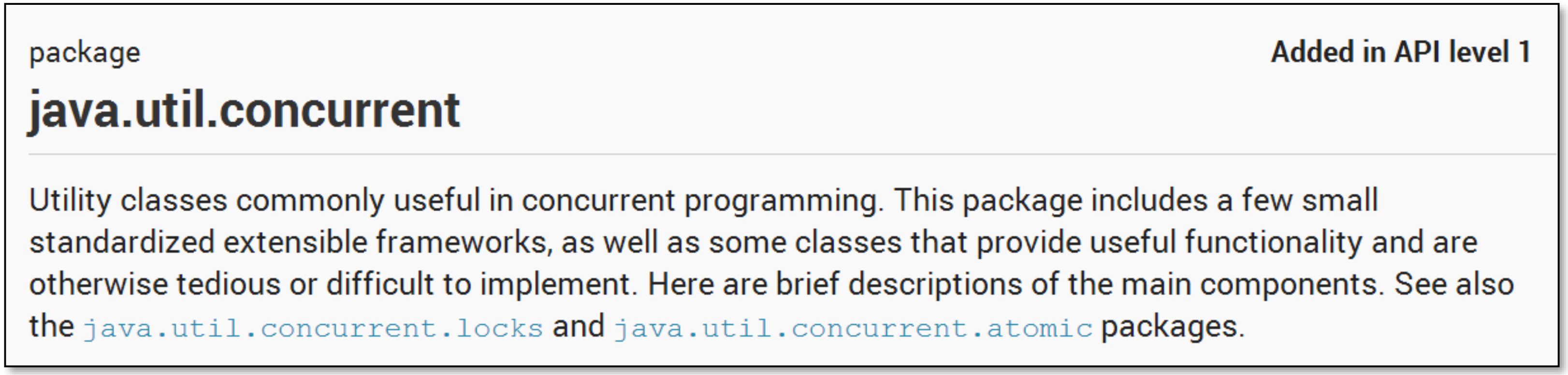
package

Added in API level 1

java.util.concurrent.locks

Interfaces and classes providing a framework for locking and waiting for conditions that is distinct from built-in synchronization and monitors. The framework permits much greater flexibility in the use of locks and conditions, at the expense of more awkward syntax.

The `Lock` interface supports locking disciplines that differ in semantics (reentrant, fair, etc), and that can be used in non-block-structured contexts including hand-over-hand and lock reordering algorithms. The main implementation is `ReentrantLock`.



package

Added in API level 1

java.util.concurrent

Utility classes commonly useful in concurrent programming. This package includes a few small standardized extensible frameworks, as well as some classes that provide useful functionality and are otherwise tedious or difficult to implement. Here are brief descriptions of the main components. See also the `java.util.concurrent.locks` and `java.util.concurrent.atomic` packages.

See developer.android.com/reference/java/util/concurrent/package-summary.html

Overview of Java Synchronizer Classes

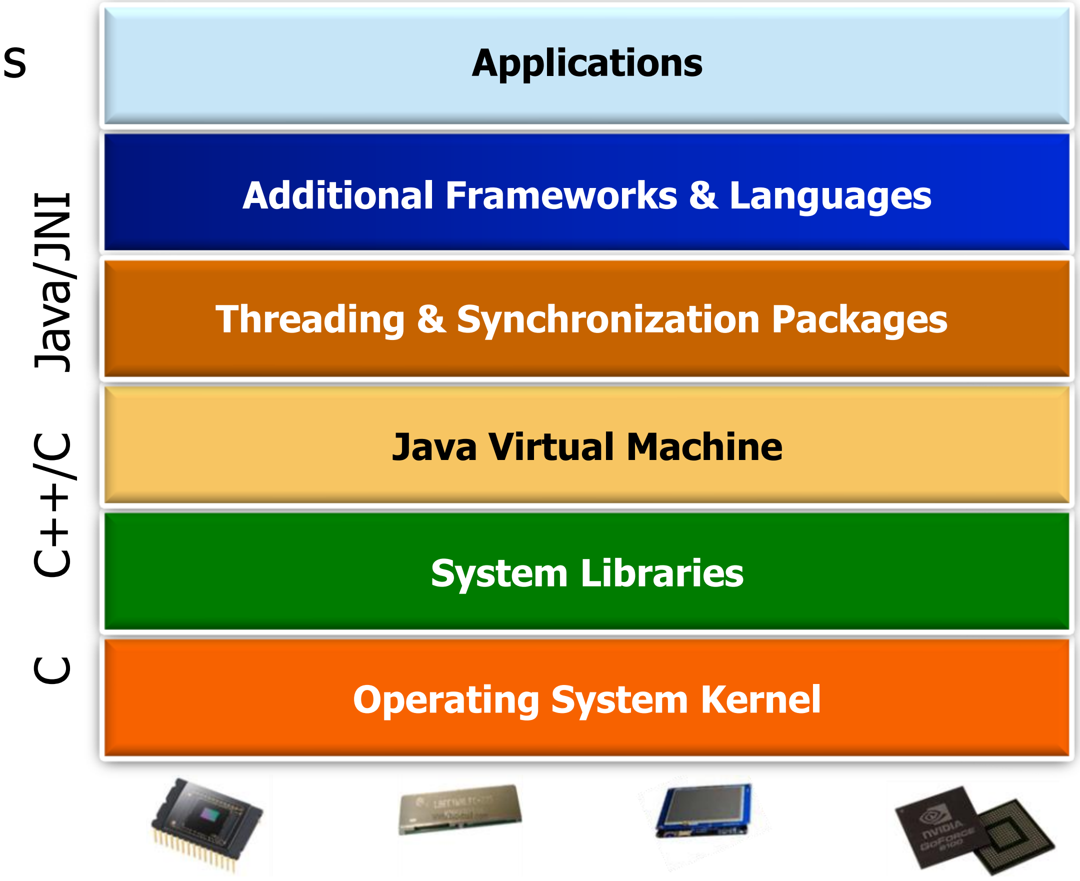
- We cover Java language features & library classes for synchronization

Java Class	Purpose
ReentrantLock	A reentrant mutual exclusion lock that extends the built-in monitor lock capabilities
Reentrant ReadWriteLock	Improves performance when resources are read much more often than written
StampedLock	A readers-writer lock that's more efficient than ReentrantReadWriteLock
Semaphore	Maintains permits that control thread access to limited # of shared resources
ConditionObject	Allows Thread to block until a condition becomes true
CountDown Latch	Allows one or more Threads to wait until a set of operations being performed in other Threads complete
Cyclic Barrier	Allows a set of Threads to all wait for each other to reach a common barrier point
Phaser	A more flexible reusable synchronization barrier

We show how these features & classes are implemented & used in Java & in practice

Overview of Java Synchronizer Classes

- These synchronizers are used extensively in Java applications & class libraries



Applications

Additional Frameworks & Languages

Threading & Synchronization Packages

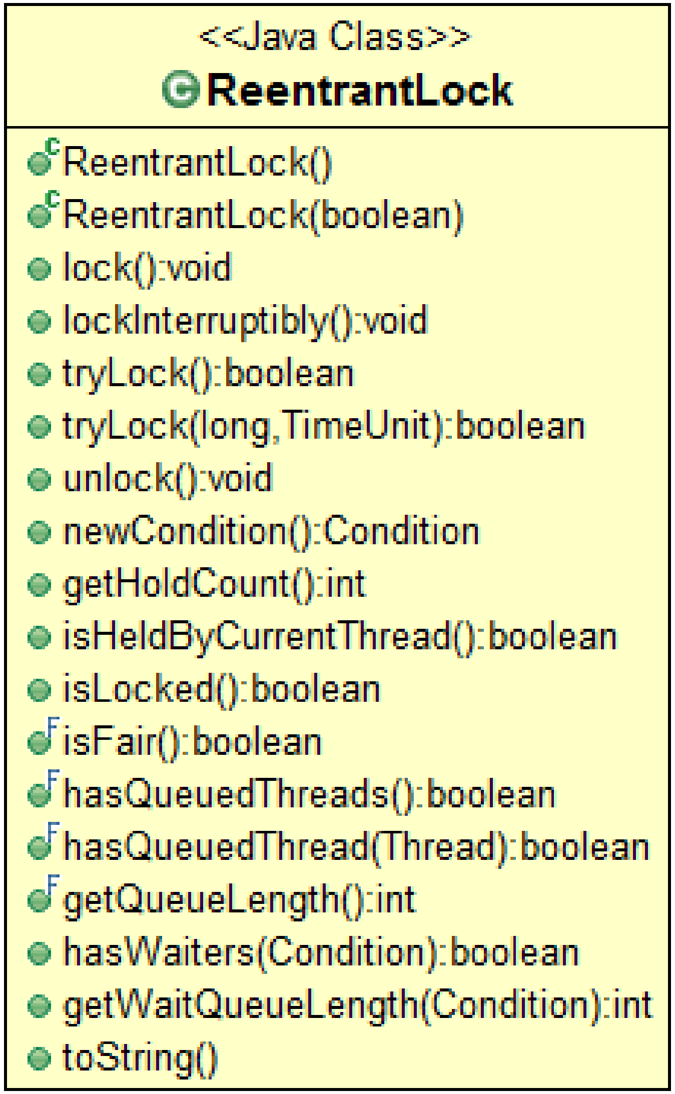
Java Virtual Machine

System Libraries

Operating System Kernel

Overview of Java Synchronizer Classes

- **ReentrantLock**
  - A mutual exclusion lock that extends built-in monitor lock capabilities



<<Java Class>>

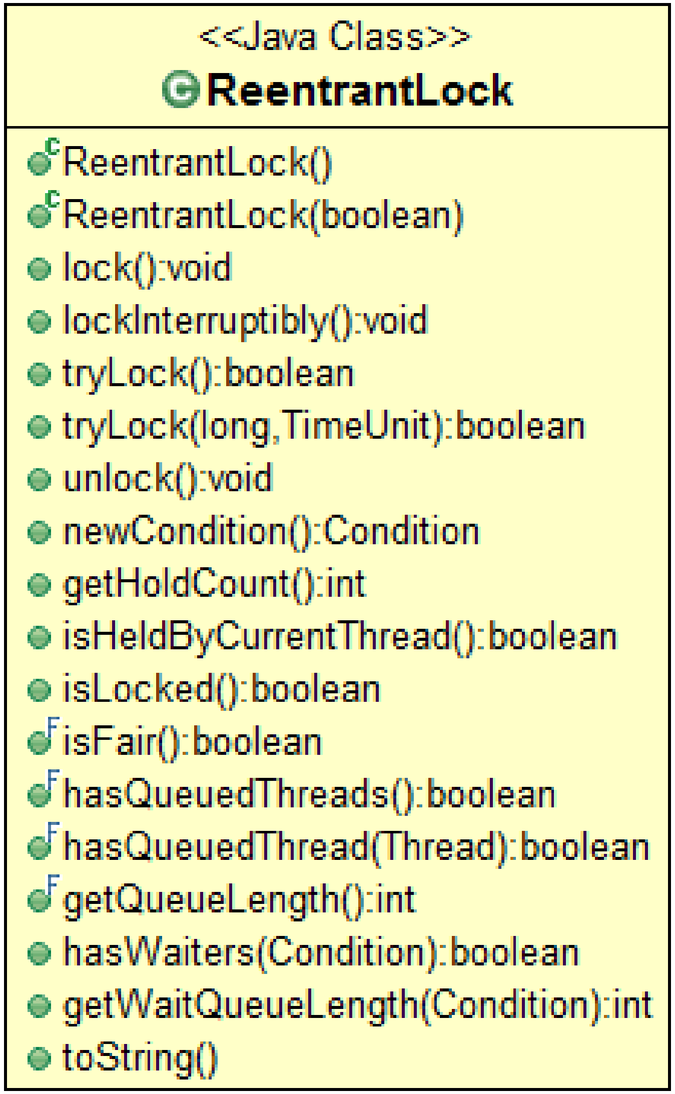
ReentrantLock

ReentrantLock()
ReentrantLock(boolean)
lock():void
lockInterruptibly():void
tryLock():boolean
tryLock(long,TimeUnit):boolean
unlock():void
newCondition():Condition
getHoldCount():int
isHeldByCurrentThread():boolean
isLocked():boolean
isFair():boolean
hasQueuedThreads():boolean
hasQueuedThread(Thread):boolean
getQueueLength():int
hasWaiters(Condition):boolean
getWaitQueueLength(Condition):int
toString()

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/locks/ReentrantLock.html

Overview of Java Synchronizer Classes

- **ReentrantLock**
  - A mutual exclusion lock that extends built-in monitor lock capabilities
  - "Reentrant" means that the thread holding the lock can reacquire it without deadlock


<<Java Class>>

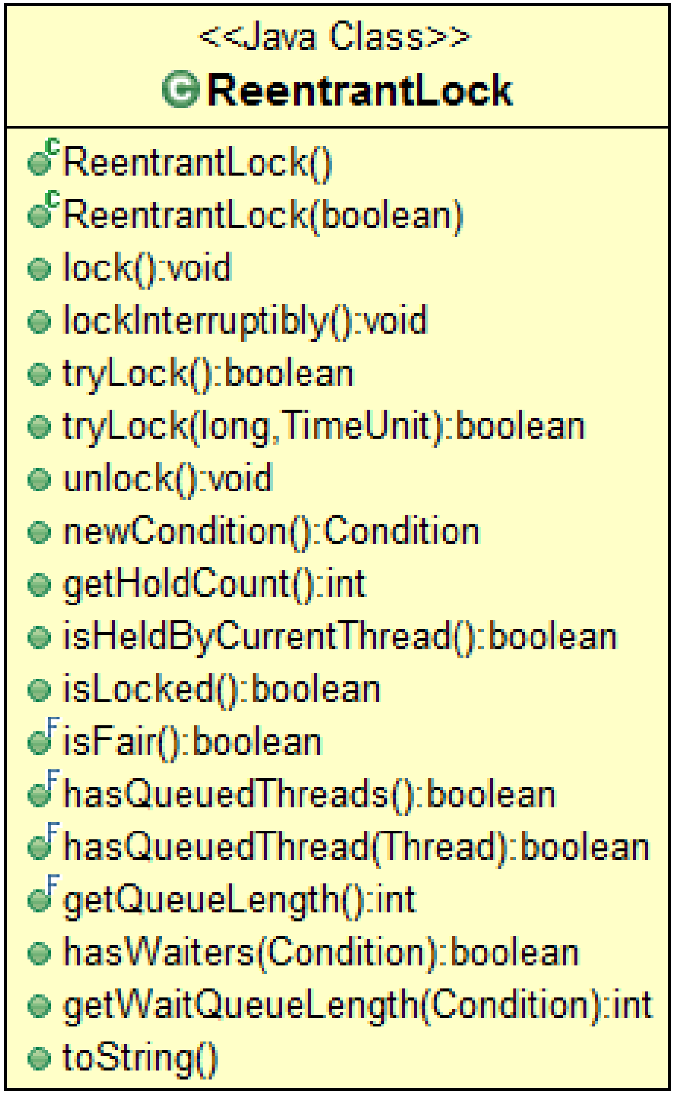
ReentrantLock

ReentrantLock()
ReentrantLock(boolean)
lock():void
lockInterruptibly():void
tryLock():boolean
tryLock(long,TimeUnit):boolean
unlock():void
newCondition():Condition
getHoldCount():int
isHeldByCurrentThread():boolean
isLocked():boolean
isFair():boolean
hasQueuedThreads():boolean
hasQueuedThread(Thread):boolean
getQueueLength():int
hasWaiters(Condition):boolean
getWaitQueueLength(Condition):int
toString()

See en.wikipedia.org/wiki/Reentrancy_(computing)

Overview of Java Synchronizer Classes

- **ReentrantLock**
  - A mutual exclusion lock that extends built-in monitor lock capabilities
  - "Reentrant" means that the thread holding the lock can reacquire it without deadlock
  - Must be "fully bracketed"
    - A thread that acquires a lock must be the one to release it



<<Java Class>>

ReentrantLock

- ReentrantLock()
- ReentrantLock(boolean)
- lock():void
- lockInterruptibly():void
- tryLock():boolean
- tryLock(long,TimeUnit):boolean
- unlock():void
- newCondition():Condition
- getHoldCount():int
- isHeldByCurrentThread():boolean
- isLocked():boolean
- isFair():boolean
- hasQueuedThreads():boolean
- hasQueuedThread(Thread):boolean
- getQueueLength():int
- hasWaiters(Condition):boolean
- getWaitQueueLength(Condition):int
- toString()

See jasleendailydiary.blogspot.com/2014/06/java-reentrant-lock.html

Overview of Java Synchronizer Classes

- **ReentrantReadWriteLock**
  - Improves performance when resources read more often than written

UNDERGRADUATE CATALOG
VANDERBILT UNIVERSITY

2014/2015

Containing general information and courses of study for the 2014/2015 session corrected to 18 June 2014

Download a pdf file of the Undergraduate Catalog (15.2 MB)

View specific sections of the catalog below

Contents

Calendar

The University

Vanderbilt University Board of Trust

Vanderbilt University Administration

Special Programs for Undergraduates

Life at Vanderbilt

Admission

Financial Information

Scholarships and Need-Based Financial Aid

College of Arts & Science

Blair School of Music

School of Engineering

Peabody College

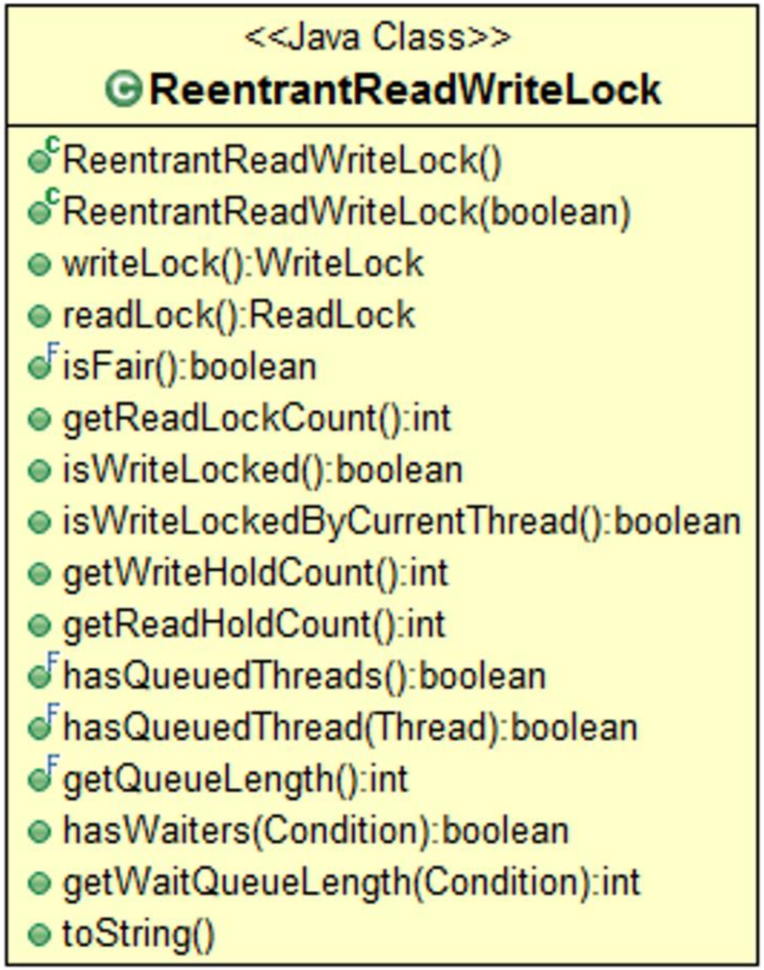
Index

This is the online version of the Undergraduate Catalog, a printed document of record issued in the fall of each year. The online version mirrors the actual printed book and is not updated until the new edition is printed for each year. For ongoing updates to departmental information, go to the website of the individual department.

ABOUT THE PDFs
Please note the catalogs listed below are in pdf format. You will need Adobe Reader to view these pages. If you do not have Adobe Reader, you can download a free copy at http://www.adobe.com/products/acrobat/readstep2.html. For more information on how to work with these pdfs, see our pdf help page.

Each pdf has bookmarks that will easily navigate you to specific sections. Select the bookmark icon in the left panel of the pdf. Note that some of the pages contain photographs. Before printing photo pages, consider the extra time and printer ink required.

Printed copies
Printed copies of the Undergraduate Catalog are available on request from the Office of Undergraduate Admissions. Catalogs of the Graduate School and post-baccalaureate professional schools of the university are available on request from the dean of the appropriate school. Contact information for these offices is available on People Finder.



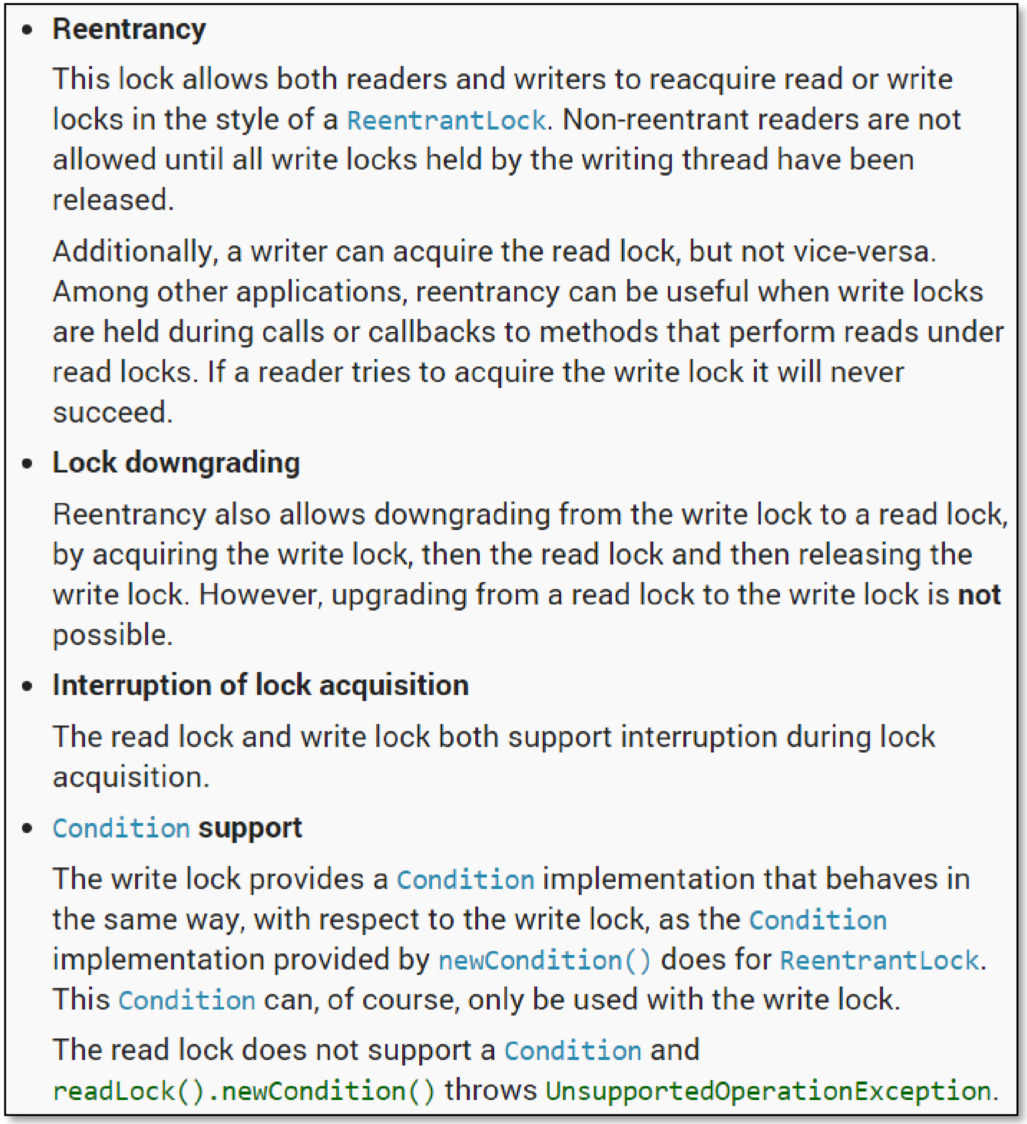
<<Java Class>>
ReentrantReadWriteLock

ReentrantReadWriteLock()
ReentrantReadWriteLock(boolean)
writeLock():WriteLock
readLock():ReadLock
isFair():boolean
getReadLockCount():int
isWriteLocked():boolean
isWriteLockedByCurrentThread():boolean
getWriteHoldCount():int
getReadHoldCount():int
hasQueuedThreads():boolean
hasQueuedThread(Thread):boolean
getQueueLength():int
hasWaiters(Condition):boolean
getWaitQueueLength(Condition):int
toString()

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/locks/ReentrantReadWriteLock.html

Overview of Java Synchronizer Classes

- **ReentrantReadWriteLock**
  - Improves performance when resources read more often than written
  - Has many features
    - Both a blessing & a curse..



- **Reentrancy**

  This lock allows both readers and writers to reacquire read or write locks in the style of a `ReentrantLock`. Non-reentrant readers are not allowed until all write locks held by the writing thread have been released.

  Additionally, a writer can acquire the read lock, but not vice-versa. Among other applications, reentrancy can be useful when write locks are held during calls or callbacks to methods that perform reads under read locks. If a reader tries to acquire the write lock it will never succeed.

- **Lock downgrading**

  Reentrancy also allows downgrading from the write lock to a read lock, by acquiring the write lock, then the read lock and then releasing the write lock. However, upgrading from a read lock to the write lock is **not** possible.

- **Interruption of lock acquisition**

  The read lock and write lock both support interruption during lock acquisition.

- `Condition` **support**

  The write lock provides a `Condition` implementation that behaves in the same way, with respect to the write lock, as the `Condition` implementation provided by `newCondition()` does for `ReentrantLock`. This `Condition` can, of course, only be used with the write lock.

  The read lock does not support a `Condition` and `readLock().newCondition()` throws `UnsupportedOperationException`.

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/locks/ReentrantReadWriteLock.html

Overview of Java Synchronizer Classes

- **StampedLock**
  - A readers-writer lock that's more efficient than a ReentrantReadWriteLock

UNDERGRADUATE CATALOG
VANDERBILT UNIVERSITY

2014/2015

Containing general information and courses of study for the 2014/2015 session corrected to 18 June 2014

Download a pdf file of the Undergraduate Catalog (15.2 MB)

View specific sections of the catalog below

Contents

Calendar

The University

Vanderbilt University Board of Trust

Vanderbilt University Administration

Special Programs for Undergraduates

Life at Vanderbilt

Admission

Financial Information

Scholarships and Need-Based Financial Aid

College of Arts & Science

Blair School of Music

School of Engineering

Peabody College

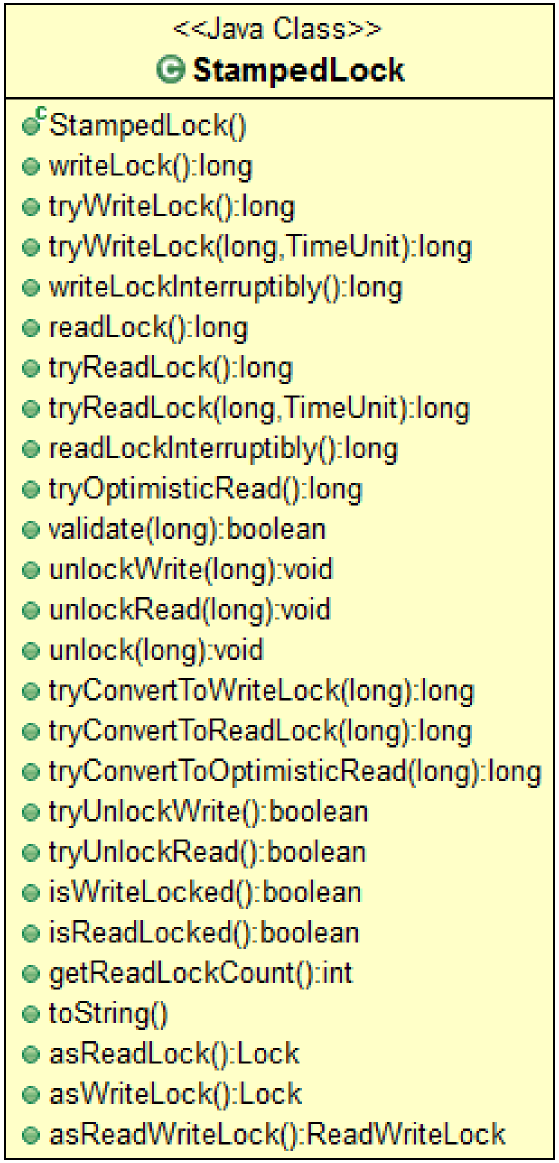
Index

This is the online version of the Undergraduate Catalog, a printed document of record issued in the fall of each year. The online version mirrors the actual printed book and is not updated until the new edition is printed for each year. For ongoing updates to departmental information, go to the website of the individual department.

ABOUT THE PDFs
Please note the catalogs listed below are in pdf format. You will need Adobe Reader to view these pages. If you do not have Adobe Reader, you can download a free copy at http://www.adobe.com/products/acrobat/readstep2.html. For more information on how to work with these pdfs, see our pdf help page.

Each pdf has bookmarks that will easily navigate you to specific sections. Select the bookmark icon in the left panel of the pdf. Note that some of the pages contain photographs. Before printing photo pages, consider the extra time and printer ink required.

Printed copies
Printed copies of the Undergraduate Catalog are available on request from the Office of Undergraduate Admissions. Catalogs of the Graduate School and post-baccalaureate professional schools of the university are available on request from the dean of the appropriate school. Contact information for these offices is available on People Finder.



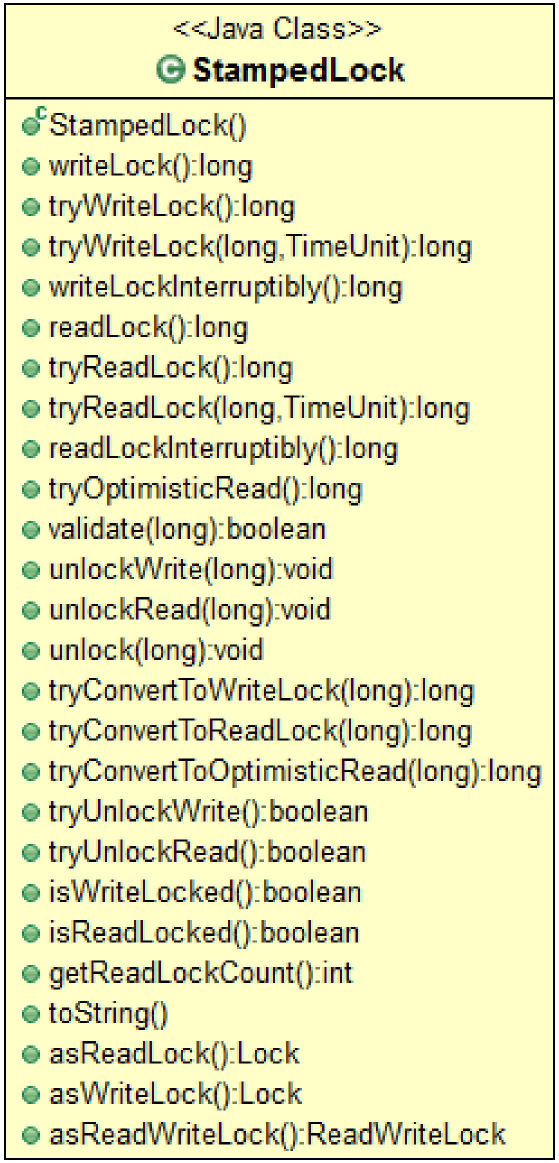
<<Java Class>>
StampedLock

- StampedLock()
- writeLock():long
- tryWriteLock():long
- tryWriteLock(long,TimeUnit):long
- writeLockInterruptibly():long
- readLock():long
- tryReadLock():long
- tryReadLock(long,TimeUnit):long
- readLockInterruptibly():long
- tryOptimisticRead():long
- validate(long):boolean
- unlockWrite(long):void
- unlockRead(long):void
- unlock(long):void
- tryConvertToWriteLock(long):long
- tryConvertToReadLock(long):long
- tryConvertToOptimisticRead(long):long
- tryUnlockWrite():boolean
- tryUnlockRead():boolean
- isWriteLocked():boolean
- isReadLocked():boolean
- getReadLockCount():int
- toString()
- asReadLock():Lock
- asWriteLock():Lock
- asReadWriteLock():ReadWriteLock

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/locks/StampedLock.html

Overview of Java Synchronizer Classes

- **StampedLock**
  - A readers-writer lock that's more efficient than a ReentrantReadWriteLock
  - Supports "optimistic" reads



<<Java Class>>
StampedLock

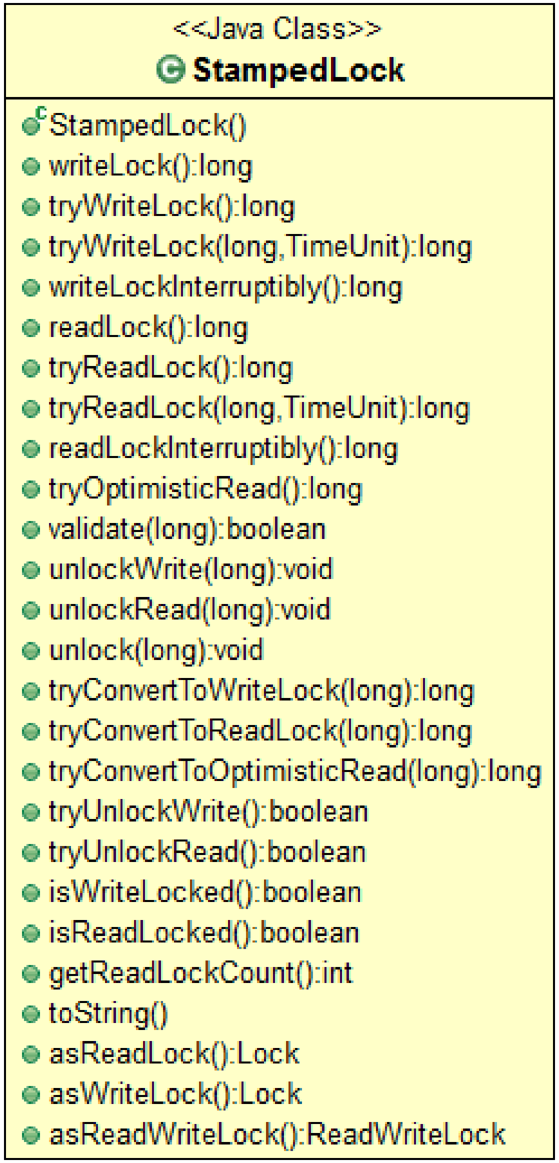
- StampedLock()
- writeLock():long
- tryWriteLock():long
- tryWriteLock(long,TimeUnit):long
- writeLockInterruptibly():long
- readLock():long
- tryReadLock():long
- tryReadLock(long,TimeUnit):long
- readLockInterruptibly():long
- tryOptimisticRead():long
- validate(long):boolean
- unlockWrite(long):void
- unlockRead(long):void
- unlock(long):void
- tryConvertToWriteLock(long):long
- tryConvertToReadLock(long):long
- tryConvertToOptimisticRead(long):long
- tryUnlockWrite():boolean
- tryUnlockRead():boolean
- isWriteLocked():boolean
- isReadLocked():boolean
- getReadLockCount():int
- toString()
- asReadLock():Lock
- asWriteLock():Lock
- asReadWriteLock():ReadWriteLock

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/locks/StampedLock.html

Overview of Java Synchronizer Classes

- **StampedLock**
  - A readers-writer lock that's more efficient than a ReentrantReadWriteLock
  - Supports "optimistic" reads
  - Also supports "lock upgrading"

Class | Classe
ECONOMY CLASS / CL ECONOMIQUE
Flight & Date | Vol et date
Seat | Place
231
26B
Where not prohibited by law
Sauf où la loi l'interdit
To | Destination
Name
Airline use | À usage Interne
0081A
YYC27670
Boarding Pass | Carte d'accès à bord
UPGRADE



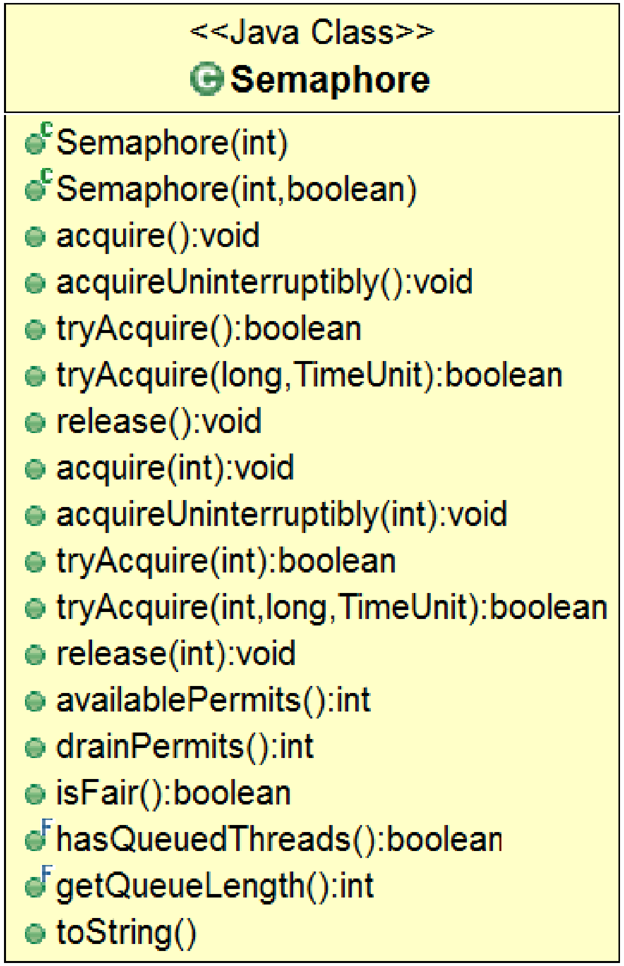
<<Java Class>>
StampedLock

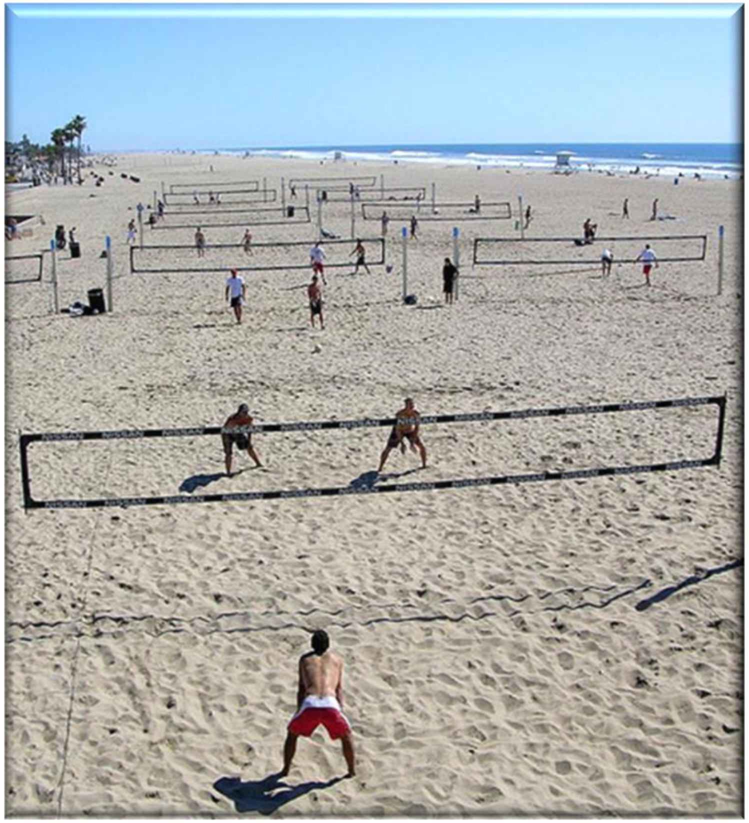
- StampedLock()
- writeLock():long
- tryWriteLock():long
- tryWriteLock(long,TimeUnit):long
- writeLockInterruptibly():long
- readLock():long
- tryReadLock():long
- tryReadLock(long,TimeUnit):long
- readLockInterruptibly():long
- tryOptimisticRead():long
- validate(long):boolean
- unlockWrite(long):void
- unlockRead(long):void
- unlock(long):void
- tryConvertToWriteLock(long):long
- tryConvertToReadLock(long):long
- tryConvertToOptimisticRead(long):long
- tryUnlockWrite():boolean
- tryUnlockRead():boolean
- isWriteLocked():boolean
- isReadLocked():boolean
- getReadLockCount():int
- toString()
- asReadLock():Lock
- asWriteLock():Lock
- asReadWriteLock():ReadWriteLock

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/locks/StampedLock.html

Overview of Java Synchronizer Classes

- **Semaphore**
  - Maintains permits that control thread access to limited # of shared resources

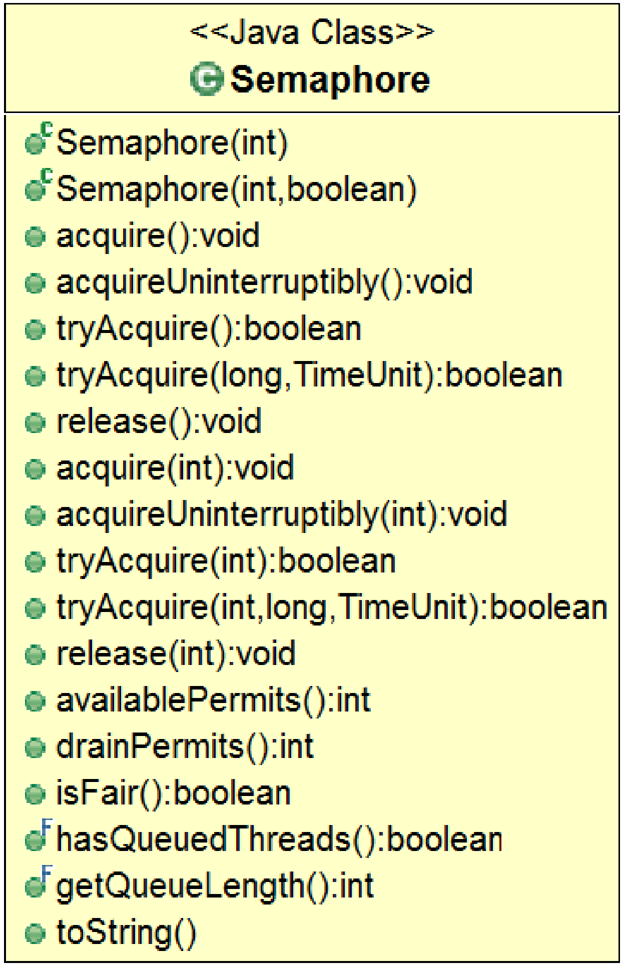




See docs.oracle.com/javase/8/docs/api/java/util/concurrent/Semaphore.html

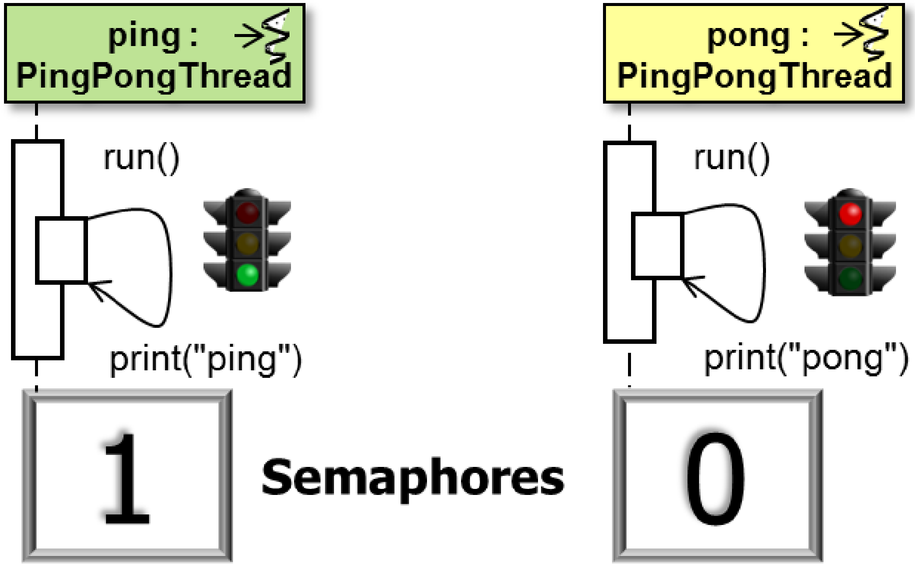
Overview of Java Synchronizer Classes

- **Semaphore**
  - Maintains permits that control thread access to limited # of shared resources
  - Operations need not be fully bracketed..



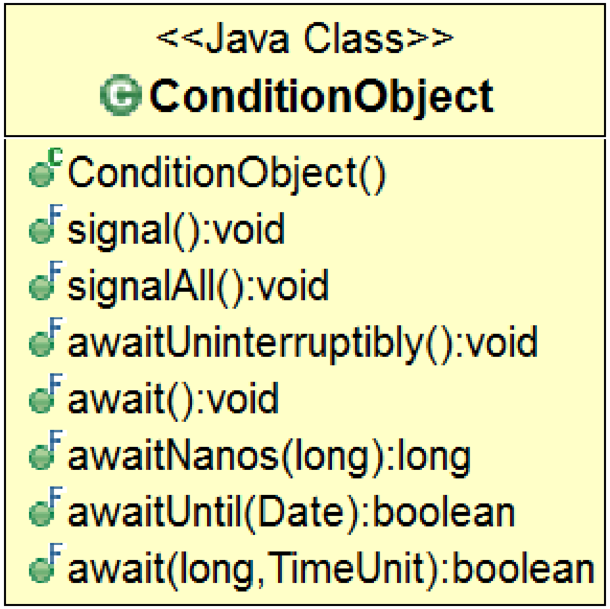
<<Java Class>>
Semaphore

- Semaphore(int)
- Semaphore(int,boolean)
- acquire():void
- acquireUninterruptibly():void
- tryAcquire():boolean
- tryAcquire(long,TimeUnit):boolean
- release():void
- acquire(int):void
- acquireUninterruptibly(int):void
- tryAcquire(int):boolean
- tryAcquire(int,long,TimeUnit):boolean
- release(int):void
- availablePermits():int
- drainPermits():int
- isFair():boolean
- hasQueuedThreads():boolean
- getQueueLength():int
- toString()



Overview of Java Synchronizer Classes

- **ConditionObject**
  - Allows a thread to wait until some condition become true



<<Java Class>>

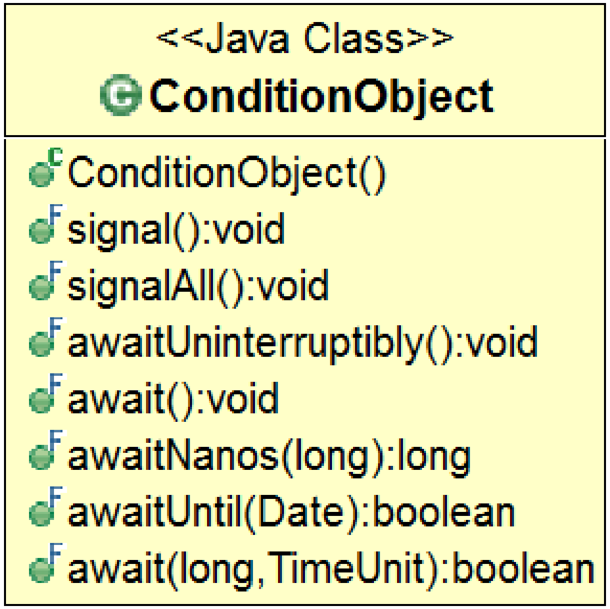
ConditionObject

- ConditionObject()
- signal():void
- signalAll():void
- awaitUninterruptibly():void
- await():void
- awaitNanos(long):long
- awaitUntil(Date):boolean
- await(long,TimeUnit):boolean

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/locks/AbstractQueuedSynchronizer.ConditionObject.html

Overview of Java Synchronizer Classes

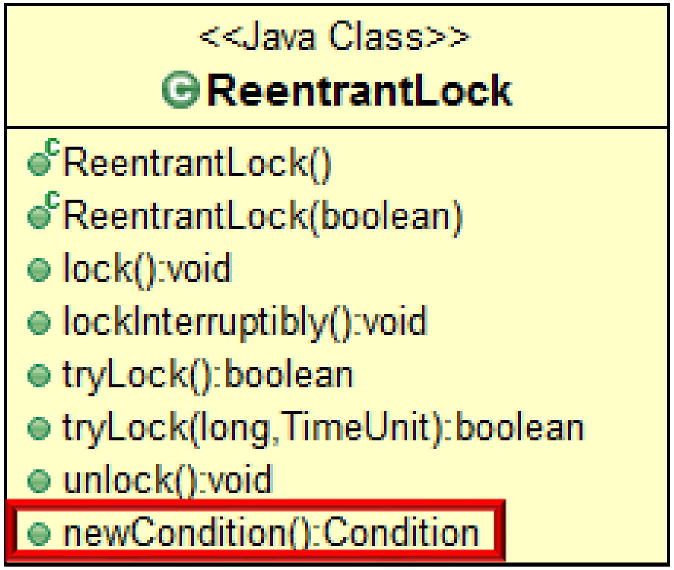
- **ConditionObject**
  - Allows a thread to wait until some condition become true
  - Always used in conjunction with a ReentrantLock



<<Java Class>>

ConditionObject

- ConditionObject()
- signal():void
- signalAll():void
- awaitUninterruptibly():void
- await():void
- awaitNanos(long):long
- awaitUntil(Date):boolean
- await(long,TimeUnit):boolean



<<Java Class>>

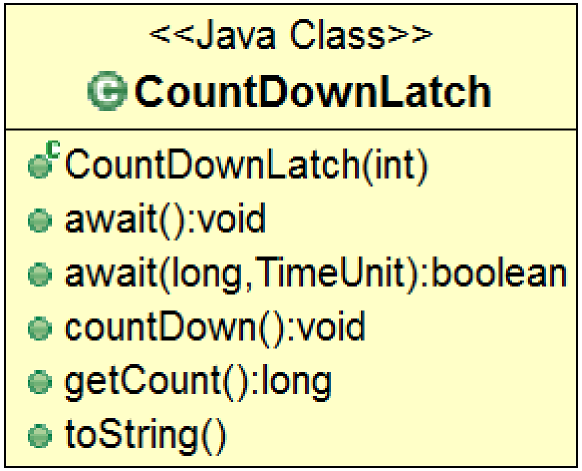
ReentrantLock

- ReentrantLock()
- ReentrantLock(boolean)
- lock():void
- lockInterruptibly():void
- tryLock():boolean
- tryLock(long,TimeUnit):boolean
- unlock():void
- newCondition():Condition

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/locks/AbstractQueuedSynchronizer.ConditionObject.html

Overview of Java Synchronizer Classes

- **CountDownLatch**
  - Allows one or more threads to wait on the completion of operations in other threads

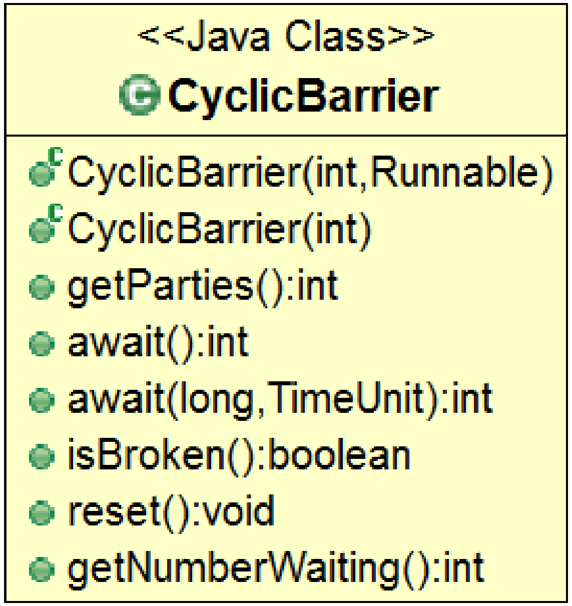


```
<<Java Class>>
CountDownLatch
CountDownLatch(int)
await():void
await(long,TimeUnit):boolean
countDown():void
getCount():long
toString()
```

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/CountDownLatch.html

Overview of Java Synchronizer Classes

- **CyclicBarrier**
  - Allows a set of threads to all wait for each other to reach a common barrier point



<<Java Class>>

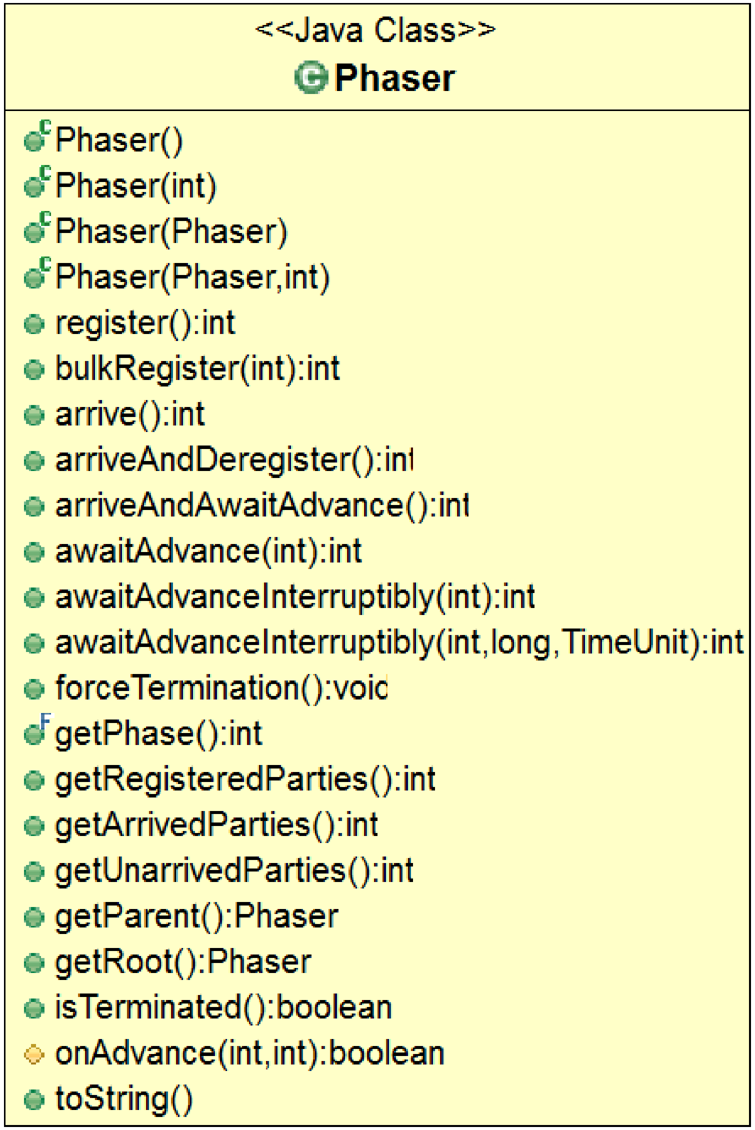
CyclicBarrier

- CyclicBarrier(int,Runnable)
- CyclicBarrier(int)
- getParties():int
- await():int
- await(long,TimeUnit):int
- isBroken():boolean
- reset():void
- getNumberWaiting():int

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/CyclicBarrier.html

Overview of Java Synchronizer Classes

- **Phaser**
  - A synchronization barrier that's more flexible & reusable than CyclicBarrier & CountDownLatch



<<Java Class>>

Phaser

- Phaser()
- Phaser(int)
- Phaser(Phaser)
- Phaser(Phaser,int)
- register():int
- bulkRegister(int):int
- arrive():int
- arriveAndDeregister():int
- arriveAndAwaitAdvance():int
- awaitAdvance(int):int
- awaitAdvanceInterruptibly(int):int
- awaitAdvanceInterruptibly(int,long,TimeUnit):int
- forceTermination():voic
- getPhase():int
- getRegisteredParties():int
- getArrivedParties():int
- getUnarrivedParties():int
- getParent():Phaser
- getRoot():Phaser
- isTerminated():boolean
- onAdvance(int,int):boolean
- toString()

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/Phaser.html

Java Synchronizer Class Usage Considerations

Java Synchronizer Class Usage Considerations

- Choosing between these synchronizers involve understanding various tradeoffs between *performance* & *productivity*

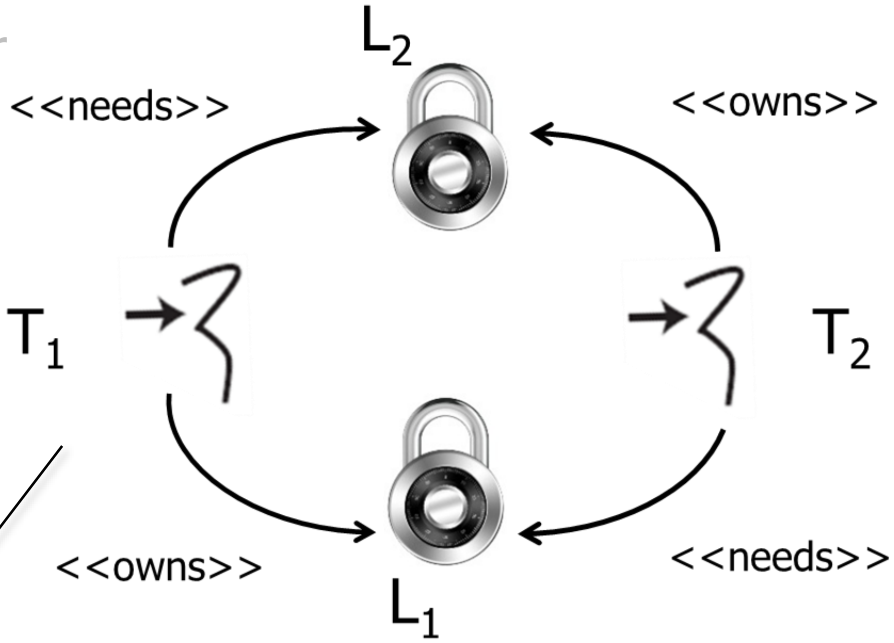
Java Synchronizer Class Usage Considerations

- Choosing between these synchronizers involve understanding various tradeoffs between *performance* & *productivity*
  - Some synchronizers (or synchronizer methods) have more overhead
    - e.g., spin locks vs. sleep locks vs. hybrid locks

See en.wikipedia.org/wiki/Spinlock & docs.oracle.com/javase/tutorial/essential/concurrency/guardmeth.html

Java Synchronizer Class Usage Considerations

- Choosing between these synchronizers involve understanding various tradeoffs between *performance* & *productivity*
  - Some synchronizers (or synchronizer methods) have more overhead
  - Some synchronizers are harder to program correctly than others
    - e.g., risk of deadlock from non-reentrant locking semantics



Deadlocks are problematic in object-oriented frameworks due to callbacks & complex control flows

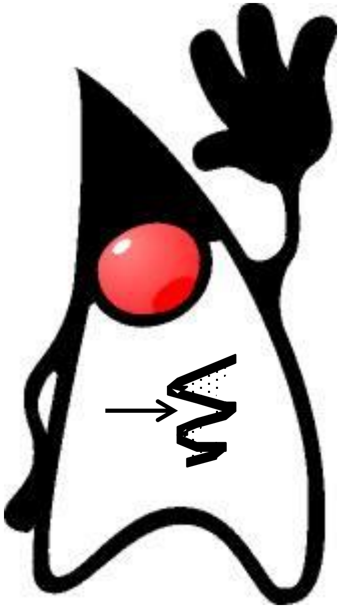
See en.wikipedia.org/wiki/Deadlock

Java Synchronizer Class Usage Considerations

- Java synchronizers differ from Java built-in monitor objects

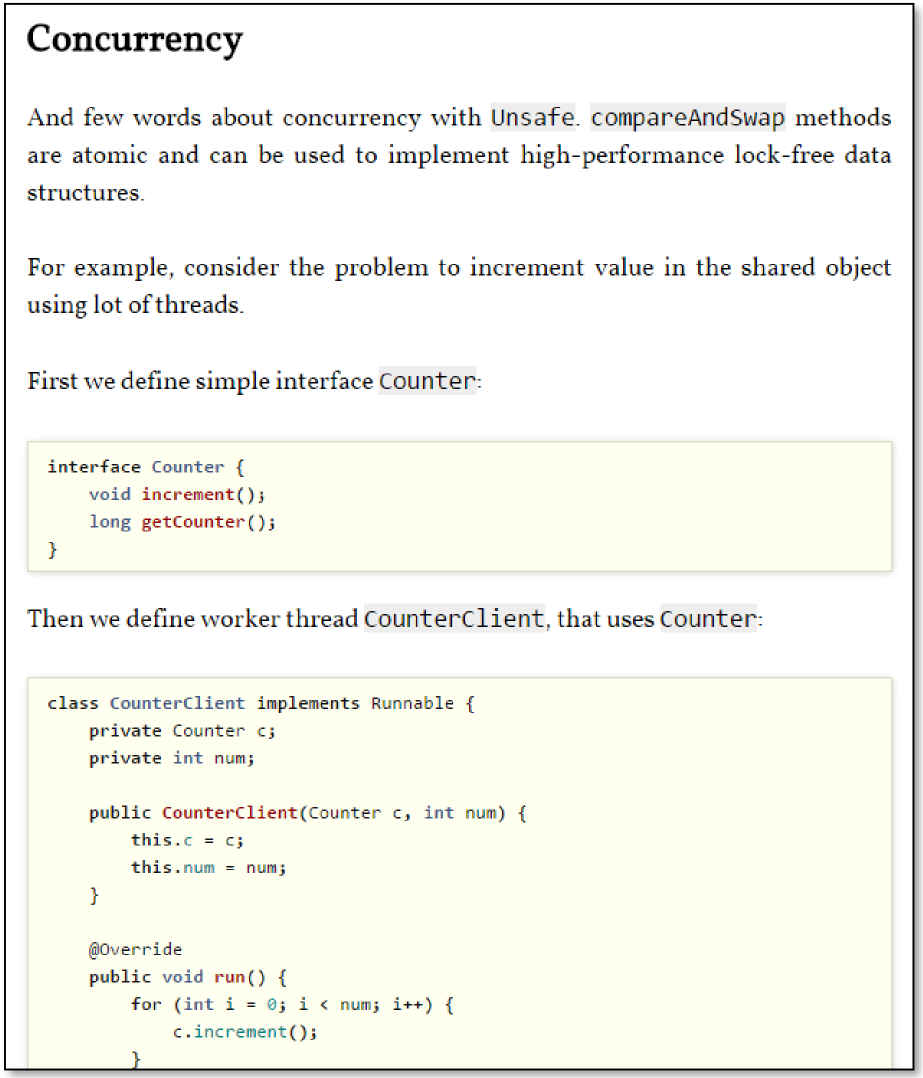
Java Synchronizer Class Usage Considerations

- Java synchronizers differ from Java built-in monitor objects, e.g.
  - They are largely written in Java rather than C/C++



Java Synchronizer Class Usage Considerations

- Java synchronizers differ from Java built-in monitor objects, e.g.
  - They are largely written in Java rather than C/C++
    - Some low-level methods written in native C/C++
      - e.g., compareAndSwapInt(), park(), unpark(), etc.



Concurrency

And few words about concurrency with `Unsafe`. `compareAndSwap` methods are atomic and can be used to implement high-performance lock-free data structures.

For example, consider the problem to increment value in the shared object using lot of threads.

First we define simple interface `Counter`:

```
interface Counter {
    void increment();
    long getCounter();
}
```

Then we define worker thread `CounterClient`, that uses `Counter`:

```
class CounterClient implements Runnable {
    private Counter c;
    private int num;

    public CounterClient(Counter c, int num) {
        this.c = c;
        this.num = num;
    }

    @Override
    public void run() {
        for (int i = 0; i < num; i++) {
            c.increment();
        }
```

See mishadoff.com/blog/java-magic-part-4-sun-dot-misc-dot-unsafe

Java Synchronizer Class Usage Considerations

- Java synchronizers differ from Java built-in monitor objects, e.g.
  - They are largely written in Java rather than C/C++
  - They provide *many* more features & have more powerful semantics

End of Overview of Java Synchronizer Classes