# Thread 4.0.0

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# Overview

**Boost.Thread** enables the use of multiple threads of execution with shared data in portable C++ code. It provides classes and functions for managing the threads themselves, along with others for synchronizing data between the threads or providing separate copies of data specific to individual threads.

The **Boost.Thread** library was originally written and designed by William E. Kempf (version 1).

Anthony Williams version (version 2) was a major rewrite designed to closely follow the proposals presented to the C++ Standards Committee, in particular N2497, N2320, N2184, N2139, and N2094

Vicente J. Botet Escriba started (version 3) the adaptation to comply with the accepted Thread C++11 library (Make use of Boost.Chrono and Boost.Move) and the Shared Locking Howard Hinnant proposal except for the upward conversions. Some minor non-standard features have been added also as thread attributes, reverse_lock, shared_lock_guard.

In order to use the classes and functions described here, you can either include the specific headers specified by the descriptions of each class or function, or include the master thread library header:

```
#include <boost/thread.hpp>
```

which includes all the other headers in turn.

# Using and building the library

Boost.Thread is configured following the conventions used to build libraries with separate source code. Boost.Thread will import/export the code only if the user has specifically asked for it, by defining either BOOST_ALL_DYN_LINK if they want all boost libraries to be dynamically linked, or BOOST_THREAD_DYN_LINK if they want just this one to be dynamically liked.

The definition of these macros determines whether BOOST_THREAD_USE_DLL is defined. If BOOST_THREAD_USE_DLL is not defined, the library will define BOOST_THREAD_USE_DLL or BOOST_THREAD_USE_LIB depending on whether the platform. On non windows platforms BOOST_THREAD_USE_LIB is defined if is not defined. In windows platforms, BOOST_THREAD_USE_LIB is defined if BOOST_THREAD_USE_DLL and the compiler supports auto-tss cleanup with Boost.Threads (for the time been Msvc and Intel)

The source code compiled when building the library defines a macros BOOST_THREAD_SOURCE that is used to import or export it. The user must not define this macro in any case.

Boost.Thread depends on some non header-only libraries.

- Boost.System: This dependency is mandatory and you will need to link with the library.
- Boost.Chrono: This dependency is optional (see below how to configure) and you will need to link with the library if you use some of the time related interfaces.
- Boost.DateTime: This dependency is mandatory, but even if Boost.DateTime is a non header-only library Boost.Thread uses only parts that are header-only, so in principle you should not need to link with the library.

It seems that there are some IDE (as e.g. Visual Studio) that deduce the libraries that a program needs to link to inspecting the sources. Such IDE could force to link to Boost.DateTime and/or Boost.Chrono.

As the single mandatory dependency is to Boost.System, the following

```
bjam toolset=msvc-11.0 --build-type=complete --with-thread
```

will install only boost_thread and boost_system.

Users of such IDE should force the Boost.Chrono and Boost.DateTime build using

```
bjam toolset=msvc-11.0 --build-type=complete --with-thread --with-chrono --with-date_time
```

The following section describes all the macros used to configure Boost.Thread.

# Configuration

### Table 1. Default Values for Configurable Features

| Feature | Anti-Feature | V2 | V3 | V4 |
|---|---|---|---|---|
| USES_CHRONO | DONT_USE_CHRONO | YES | YES | YES |
| PROVIDES_INTERRUPTIONS | DONT_PROVIDE_INTERRUPTIONS | YES | YES | YES |
| THROW_IF_PRECONDITION_NOT_SATISFIED | - | NO | NO | NO |
| PROVIDES_PROMISE_LAZY | DONT_PROVIDE_PROMISE_LAZY | YES | NO | NO |
| PROVIDES_BASIC_THREAD_ID | DONT_PROVIDE_BASIC_THREAD_ID | NO | YES | YES |
| PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN | DONT_PROVIDE_GENERIC_SHARED_MUTEX_ON_WIN | NO | YES | YES |
| PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION | DONT_PROVIDE_SHARED_MUTEX_UPWARDS_CONVERSION | NO | YES | YES |
| PROVIDES_EXPLICIT_LOCK_CONVERSION | DONT_PROVIDE_EXPLICIT_LOCK_CONVERSION | NO | YES | YES |
| PROVIDES_FUTURE | DONT_PROVIDE_FUTURE | NO | YES | YES |
| PROVIDES_FUTURE_CTOR_ALLOCATORS | DONT_PROVIDE_FUTURE_CTOR_ALLOCATORS | NO | YES | YES |
| PROVIDES_THREAD_DESTRUCTOR_CALLS_TERMINATE_IF_JOINABLE | DONT_PROVIDE_THREAD_DESTRUCTOR_CALLS_TERMINATE_IF_JOINABLE | NO | YES | YES |
| PROVIDES_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE | DONT_PROVIDE_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE | NO | YES | YES |
| PROVIDES_ONCE_CXX11 | DONT_PROVIDE_ONCE_CXX11 | NO | YES | YES |
| USES_MOVE | DONT_USE_MOVE | NO | YES | YES |
| USES_DATETIME | DONT_USE_DATETIME | YES | YES | NO |
| PROVIDES_THREAD_EQ | DONT_PROVIDE_THREAD_EQ | YES | YES | NO |

| Feature | Anti-Feature | V2 | V3 | V4 |
|---|---|---|---|---|
| PROVIDES_CONDITION | DONT_PROVIDE_CONDITION | YES | YES | NO |
| PROVIDES_NESTED_LOCKS | DONT_PROVIDE_NESTED_LOCKS | YES | YES | NO |
| PROVIDES_SIGNATURE_PACKAGED_TASK | DONT_PROVIDE_SIGNATURE_PACKAGED_TASK | NO | NO | YES |
| PROVIDES_FUTURE_INVALID_AFTER_GET | DONT_PROVIDE_FUTURE_INVALID_AFTER_GET | NO | NO | YES |
| PROVIDES_VARIADIC_THREAD | DONT_PROVIDE_VARIADIC_THREAD | NO | NO | C++11 |

## Boost.Chrono

Boost.Thread uses by default Boost.Chrono for the time related functions and define `BOOST_THREAD_USES_CHRONO` if `BOOST_THREAD_DONT_USE_CHRONO` is not defined. The user should define `BOOST_THREAD_DONT_USE_CHRONO` for compilers that don't work well with Boost.Chrono.

## Boost.Move

Boost.Thread uses by default an internal move semantic implementation. Since version 3.0.0 you can use the move emulation emulation provided by Boost.Move.

When `BOOST_THREAD_VERSION==2` define `BOOST_THREAD_USES_MOVE` if you want to use Boost.Move interface. When `BOOST_THREAD_VERSION>=3` define `BOOST_THREAD_DONT_USE_MOVE` if you don't want to use Boost.Move interface.

## Boost.DateTime

The Boost.DateTime time related functions introduced in Boost 1.35.0, using the Boost.Date_Time library are deprecated. These include (but are not limited to):

- `boost::this_thread::sleep()`
- `timed_join()`
- `timed_wait()`
- `timed_lock()`

When `BOOST_THREAD_VERSION<=3` define `BOOST_THREAD_DONT_USE_DATETIME` if you don't want to use Boost.DateTime related interfaces. When `BOOST_THREAD_VERSION>3` define `BOOST_THREAD_USES_DATETIME` if you want to use Boost.DateTime related interfaces.

### `boost::thread::oprator==` deprecated

The following nested typedefs are deprecated:

- `boost::thread::oprator==`
- `boost::thread::oprator!=`

When `BOOST_THREAD_PROVIDES_THREAD_EQ` is defined Boost.Thread provides these deprecated feature.

Use instead

- `boost::thread::id::oprator==`
- `boost::thread::id::oprator!=`

**Warning**

This is a breaking change respect to version 1.x.

When `BOOST_THREAD_VERSION>=4` define `BOOST_THREAD_PROVIDES_THREAD_EQ` if you want this feature. When `BOOST_THREAD_VERSION<4` define `BOOST_THREAD_DONT_PROVIDE_THREAD_EQ` if you don't want this feature.

## boost::condition deprecated

`boost::condition` is deprecated. When `BOOST_THREAD_PROVIDES_CONDITION` is defined Boost.Thread provides this deprecated feature.

Use instead `boost::condition_variable_any`.

**Warning**

This is a breaking change respect to version 1.x.

When `BOOST_THREAD_VERSION>3` define `BOOST_THREAD_PROVIDES_CONDITION` if you want this feature. When `BOOST_THREAD_VERSION<=3` define `BOOST_THREAD_DONT_PROVIDE_CONDITION` if you don't want this feature.

## Mutex nested lock types deprecated

The following nested typedefs are deprecated:

- `boost::mutex::scoped_lock`,
- `boost::mutex::scoped_try_lock`,
- `boost::timed_mutex::scoped_lock`
- `boost::timed_mutex::scoped_try_lock`
- `boost::timed_mutex::timed_scoped_timed_lock`
- `boost::recursive_mutex::scoped_lock`,
- `boost::recursive_mutex::scoped_try_lock`,
- `boost::recursive_timed_mutex::scoped_lock`
- `boost::recursive_timed_mutex::scoped_try_lock`
- `boost::recursive_timed_mutex::timed_scoped_timed_lock`

When `BOOST_THREAD_PROVIDES_NESTED_LOCKS` is defined Boost.Thread provides these deprecated feature.

Use instead * `boost::unique_lock<boost::mutex>`, * `boost::unique_lock<boost::mutex>` with the `try_to_lock_t` constructor, * `boost::unique_lock<boost::timed_mutex>` * `boost::unique_lock<boost::timed_mutex>` with the `try_to_lock_t` constructor * `boost::unique_lock<boost::timed_mutex>` * `boost::unique_lock<boost::recurs-`

ive_mutex>, * boost::unique_lock<boost::recursive_mutex> with the try_to_lock_t constructor, * boost::unique_lock<boost::recursive_timed_mutex> * boost::unique_lock<boost::recursive_timed_mutex> with the try_to_lock_t constructor * boost::unique_lock<boost::recursive_timed_mutex>

**Warning**

This is a breaking change respect to version 1.x.

When BOOST_THREAD_VERSION>=4 define BOOST_THREAD_PROVIDES_NESTED_LOCKS if you want these features. When BOOST_THREAD_VERSION<4 define BOOST_THREAD_DONT_PROVIDE_NESTED_LOCKS if you don't want thes features.

## thread::id

Boost.Thread uses by default a thread::id on Posix based on the pthread type (BOOST_THREAD_PROVIDES_BASIC_THREAD_ID). For backward compatibility and also for compilers that don't work well with this modification the user can define BOOST_THREAD_DONT_PROVIDE_BASIC_THREAD_ID.

Define BOOST_THREAD_DONT_PROVIDE_BASIC_THREAD_ID if you don't want these features.

## Shared Locking Generic

The shared mutex implementation on Windows platform provides currently less functionality than the generic one that is used for PTheads based platforms. In order to have access to these functions, the user needs to define BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN to use the generic implementation, that while could be less efficient, provides all the functions.

When BOOST_THREAD_VERSION==2 define BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN if you want these features. When BOOST_THREAD_VERSION>=3 define BOOST_THREAD_DONT_PROVIDE_GENERIC_SHARED_MUTEX_ON_WIN if you don't want these features.

## Shared Locking Upwards Conversion

Boost.Threads includes in version 3 the Shared Locking Upwards Conversion as defined in Shared Locking. These conversions need to be used carefully to avoid deadlock or livelock. The user need to define explicitly BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION to get these upwards conversions.

When BOOST_THREAD_VERSION==2 define BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION if you want these features. When BOOST_THREAD_VERSION>=3 define BOOST_THREAD_DONT_PROVIDE_SHARED_MUTEX_UPWARDS_CONVERSION if you don't want these features.

## Explicit Lock Conversion

In Shared Locking the lock conversions are explicit. As this explicit conversion breaks the lock interfaces, it is provided only if the BOOST_THREAD_PROVIDES_EXPLICIT_LOCK_CONVERSION is defined.

When BOOST_THREAD_VERSION==2 define BOOST_THREAD_PROVIDES_EXPLICIT_LOCK_CONVERSION if you want these features. When BOOST_THREAD_VERSION==3 define BOOST_THREAD_DONT_PROVIDE_EXPLICIT_LOCK_CONVERSION if you don't want these features.

## unique_future versus future

C++11 uses std::future. Versions of Boost.Thread previous to version 3.0.0 uses boost:unique_future. Since version 3.0.0 boost::future replaces boost::unique_future when BOOST_THREAD_PROVIDES_FUTURE is defined. The documentation doesn't contains anymore however boost::unique_future.

When BOOST_THREAD_VERSION==2 define BOOST_THREAD_PROVIDES_FUTURE if you want to use boost::future. When BOOST_THREAD_VERSION>=3 define BOOST_THREAD_DONT_PROVIDE_FUTURE if you want to use boost::unique_future.

## promise lazy initialization

C++11 promise initialize the associated state at construction time. Versions of Boost.Thread previous to version 3.0.0 initialize it lazily at any point in time in which this associated state is needed.

Since version 3.0.0 this difference in behavior can be configured. When `BOOST_THREAD_PROVIDES_PROMISE_LAZY` is defined the backward compatible behavior is provided.

When `BOOST_THREAD_VERSION==2` define `BOOST_THREAD_DONT_PROVIDE_PROMISE_LAZY` if you want to use boost::future. When `BOOST_THREAD_VERSION>=3` define `BOOST_THREAD_PROVIDES_PROMISE_LAZY` if you want to use boost::unique_future.

## promise Allocator constructor

C++11 std::promise provides constructors with allocators.

```
template <typename R>
class promise
{
  public:
    template <class Allocator>
    explicit promise(allocator_arg_t, Allocator a);
  // ...
};
template <class R, class Alloc> struct uses_allocator<promise<R>,Alloc>: true_type {};
```

where

```
struct allocator_arg_t { };
constexpr allocator_arg_t allocator_arg = allocator_arg_t();

template <class T, class Alloc> struct uses_allocator;
```

Since version 3.0.0 Boost.Thread implements this constructor using the following interface

```
namespace boost
{
  typedef container::allocator_arg_t allocator_arg_t;
  constexpr allocator_arg_t allocator_arg = {};

  namespace container
  {
    template <class R, class Alloc>
    struct uses_allocator<promise<R>,Alloc>: true_type {};
  }
  template <class T, class Alloc>
  struct uses_allocator : public container::uses_allocator<T, Alloc> {};
}
```

which introduces a dependency on Boost.Container. This feature is provided only if `BOOST_THREAD_PROVIDES_FUTURE_CTOR_ALLOCATORS` is defined.

When `BOOST_THREAD_VERSION==2` define `BOOST_THREAD_PROVIDES_FUTURE_CTOR_ALLOCATORS` if you want these features. When `BOOST_THREAD_VERSION>=3` define `BOOST_THREAD_DONT_PROVIDE_FUTURE_CTOR_ALLOCATORS` if you don't want these features.

## Call to terminate if joinable

C++11 has a different semantic for the thread destructor and the move assignment. Instead of detaching the thread, calls to terminate() if the thread was joinable. When `BOOST_THREAD_PROVIDES_THREAD_DESTRUCTOR_CALLS_TERMINATE_IF_JOINABLE` and `BOOST_THREAD_PROVIDES_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE` is defined Boost.Thread provides the C++ semantic.

When `BOOST_THREAD_VERSION==2` define `BOOST_THREAD_PROVIDES_THREAD_DESTRUCTOR_CALLS_TERMINATE_IF_JOINABLE` if you want these features. When `BOOST_THREAD_VERSION>=3` define `BOOST_THREAD_DONT_PROVIDE_THREAD_DESTRUCTOR_CALLS_TERMINATE_IF_JOINABLE` if you don't want these features.

When `BOOST_THREAD_VERSION==2` define `BOOST_THREAD_PROVIDES_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE` if you want these features. When `BOOST_THREAD_VERSION>=3` define `BOOST_THREAD_DONT_PROVIDE_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE` if you don't want these features.

## once_flag

C++11 defines a default constructor for once_flag. When `BOOST_THREAD_PROVIDES_ONCE_CXX11` is defined Boost.Thread provides this C++ semantics. In this case, the previous aggregate syntax is not supported.

```
boost::once_flag once = BOOST_ONCE_INIT;
```

You should now just do

```
boost::once_flag once;
```

When `BOOST_THREAD_VERSION==2` define `BOOST_THREAD_PROVIDES_ONCE_CXX11` if you want these features. When `BOOST_THREAD_VERSION>=3` define `BOOST_THREAD_DONT_PROVIDE_ONCE_CXX11` if you don't want these features.

## Signature parameter for packaged_task

C++11 packaged task class has a Signature template parameter. When `BOOST_THREAD_PROVIDES_SIGNATURE_PACKAGED_TASK` is defined Boost.Thread provides this C++ feature.

> **Warning**
>
> This is a breaking change respect to version 3.x.

When `BOOST_THREAD_VERSION<4` define `BOOST_THREAD_PROVIDES_SIGNATURE_PACKAGED_TASK` if you want this feature. When `BOOST_THREAD_VERSION>=4` define `BOOST_THREAD_DONT_PROVIDE_SIGNATURE_PACKAGED_TASK` if you don't want this feature.

## -var thread constructor with variadic rvalue parameters

C++11 thread constructor accep a variable number of rvalue argumentshas. When `BOOST_THREAD_PROVIDES_VARIADIC_THREAD` is defined Boost.Thread provides this C++ feature if the following are not defined

- BOOST_NO_CXX11_VARIADIC_TEMPLATES
- BOOST_NO_CXX11_DECLTYPE
- BOOST_NO_CXX11_RVALUE_REFERENCES
- BOOST_NO_CXX11_HDR_TUPLE

When `BOOST_THREAD_VERSION>4` define `BOOST_THREAD_DONT_PROVIDE_VARIADIC_THREAD` if you don't want this feature.

## future<>::get() invalidates the future

C++11 future<>::get() invalidates the future once its value has been obtained. When `BOOST_THREAD_PROVIDES_FUTURE_INVALID_AFTER_GET` is defined Boost.Thread provides this C++ feature.

> **Warning**
>
> This is a breaking change respect to version 3.x.

When `BOOST_THREAD_VERSION<4` define `BOOST_THREAD_PROVIDES_FUTURE_INVALID_AFTER_GET` if you want this feature. When `BOOST_THREAD_VERSION>=4` define `BOOST_THREAD_DONT_PROVIDE_FUTURE_INVALID_AFTER_GET` if you don't want this feature.

## Interruptions

Thread interruption, while useful, makes any interruption point less efficient than if the thread were not interruptible.

When `BOOST_THREAD_PROVIDES_INTERRUPTIONS` is defined Boost.Thread provides interruptions. When `BOOST_THREAD_DONT_PROVIDE_INTERRUPTIONS` is defined Boost.Thread don't provide interruption.

Boost.Thread defines BOOST_THREAD_PROVIDES_INTERRUPTIONS if neither BOOST_THREAD_PROVIDES_INTERRUPTIONS nor BOOST_THREAD_DONT_PROVIDE_INTERRUPTIONS are defined, so that there is no compatibility break.

## Version

`BOOST_THREAD_VERSION` defines the Boost.Thread version. The default version is 2. In this case the following breaking or extending macros are defined if the opposite is not requested:

- `BOOST_THREAD_PROVIDES_PROMISE_LAZY`

The user can request the version 3 by defining `BOOST_THREAD_VERSION` to 3. In this case the following breaking or extending macros are defined if the opposite is not requested:

- Breaking change `BOOST_THREAD_PROVIDES_EXPLICIT_LOCK_CONVERSION`
- Conformity & Breaking change `BOOST_THREAD_PROVIDES_FUTURE`
- Uniformity `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN`
- Extension `BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION`
- Conformity `BOOST_THREAD_PROVIDES_FUTURE_CTOR_ALLOCATORS`
- Conformity & Breaking change BOOST_THREAD_PROVIDES_THREAD_DESTRUCTOR_CALLS_TERMINATE_IF_JOINABLE
- Conformity & Breaking change BOOST_THREAD_PROVIDES_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE
- Conformity & Breaking change `BOOST_THREAD_PROVIDES_ONCE_CXX11`
- Breaking change `BOOST_THREAD_DONT_PROVIDE_PROMISE_LAZY`

The default value for `BOOST_THREAD_VERSION` will be changed to 3 since Boost 1.54.

The user can request the version 4 by defining `BOOST_THREAD_VERSION` to 4. In this case the following breaking or extending macros are defined if the opposite is not requested:

- Conformity & Breaking change `BOOST_THREAD_PROVIDES_SIGNATURE_PACKAGED_TASK`

- Conformity & Breaking change `BOOST_THREAD_PROVIDES_FUTURE_INVALID_AFTER_GET`
- Conformity `BOOST_THREAD_PROVIDES_VARIADIC_THREAD`
- Breaking change `BOOST_THREAD_DONT_PROVIDE_THREAD_EQ`
- Breaking change `BOOST_THREAD_DONT_USE_DATETIME`

The default value for `BOOST_THREAD_VERSION` will be changed to 4 since Boost 1.56.

# Limitations

Some compilers don't work correctly with some of the added features.

## SunPro

If __SUNPRO_CC < 0x5100 the library defines

- `BOOST_THREAD_DONT_USE_MOVE`

If __SUNPRO_CC < 0x5100 the library defines

- `BOOST_THREAD_DONT_PROVIDE_FUTURE_CTOR_ALLOCATORS`

## VACPP

If __IBMCPP__ < 1100 the library defines

- `BOOST_THREAD_DONT_USE_CHRONO`
- `BOOST_THREAD_USES_DATE`

And Boost.Thread doesn't links with Boost.Chrono.

## WCE

If _WIN32_WCE && _WIN32_WCE==0x501 the library defines

- `BOOST_THREAD_DONT_PROVIDE_FUTURE_CTOR_ALLOCATORS`

# History

## Version 4.0.0 - boost 1.53

**Deprecated features:**

> **Warning**
>
> Deprecated features since boost 1.53 will be available only until boost 1.58.

- C++11 compliance: packaged_task<R> is deprecated, use instead packaged_task<R()>. See BOOST_THREAD_PROVIDES_SIGNATURE_PACKAGED_TASK and BOOST_THREAD_DONT_PROVIDE_SIGNATURE_PACKAGED_TASK
- #7537 deprecate Mutex::scoped_lock and scoped_try_lock and boost::condition

**New Features:**

- #6270 c++11 compliance: Add thread constructor from movable callable and movable arguments Provided when BOOST_THREAD_PROVIDES_VARIADIC_THREAD is defined (Default value from Boost 1.55): See BOOST_THREAD_PROVIDES_VARIADIC_THREAD and BOOST_THREAD_DONT_PROVIDE_VARIADIC_THREAD.
- #7279 C++11 compliance: Add noexcept in system related functions
- #7280 C++11 compliance: Add promise::...at_thread_exit functions
- #7281 C++11 compliance: Add ArgTypes to packaged_task template. Provided when BOOST_THREAD_PROVIDES_SIGNATURE_PACKAGED_TASK is defined (Default value from Boost 1.55). See BOOST_THREAD_PROVIDES_SIGNATURE_PACKAGED_TASK and BOOST_THREAD_DONT_PROVIDE_SIGNATURE_PACKAGED_TASK.
- #7282 C++11 compliance: Add packaged_task::make_ready_at_thread_exit function
- #7412 C++11 compliance: Add async from movable callable and movable arguments Provided when BOOST_THREAD_PROVIDES_VARIADIC_THREAD and BOOST_THREAD_PROVIDES_SIGNATURE_PACKAGED_TASK are defined (Default value from Boost 1.55): See BOOST_THREAD_PROVIDES_SIGNATURE_PACKAGED_TASK and BOOST_THREAD_DONT_PROVIDE_SIGNATURE_PACKAGED_TASK, BOOST_THREAD_PROVIDES_VARIADIC_THREAD and BOOST_THREAD_DONT_PROVIDE_VARIADIC_THREAD.
- #7413 C++11 compliance: Add async when the launch policy is deferred.
- #7414 C++11 compliance: future::get post-condition should be valid()==false.
- #7422 Provide a condition variable with zero-overhead performance penality.
- #7444 Async: Add make_future/make_shared_future.
- #7540 Threads: Add a helper class that join a thread on destruction.
- #7541 Threads: Add a thread wrapper class that joins on destruction.
- #7575 C++11 compliance: A future created by async should "join" in the destructor.
- #7587 Synchro: Add strict_lock and nested_strict_lock.
- #7588 Synchro: Split the locks.hpp in several files to limit dependencies.
- #7590 Synchro: Add lockable concept checkers based on Boost.ConceptCheck.
- #7591 Add lockable traits that can be used with enable_if.

- #7592 Synchro: Add a null_mutex that is a no-op and that is a model of UpgardeLockable.
- #7593 Synchro: Add a externally_locked class.
- #7594 Threads: Allow to disable thread interruptions.

**Fixed Bugs:**

- #7464 BOOST_TEST(n_alive == 1); fails due to race condition in a regression test tool.
- #7657 Serious performance and memory consumption hit if condition_variable methods condition notify_one or notify_all is used repeatedly.
- #7665 this_thread::sleep_for no longer uses steady_clock in thread.
- #7668 thread_group::join_all() should check whether its threads are joinable.
- #7669 thread_group::join_all() should catch resource_deadlock_would_occur.
- #7672 lockable_traits.hpp syntax error: "defined" token misspelled.
- #7798 boost::future set_wait_callback thread safety issues.
- #7808 Incorrect description of effects for this_thread::sleep_for and this_thread::sleep_until.
- #7812 Returns: cv_status::no_timeout if the call is returning because the time period specified by rel_time has elapsed, cv_status::timeout otherwise.
- #7874 compile warning: thread.hpp:342: warning: type attributes are honored only at type definition.
- #7875 BOOST_THREAD_THROW_IF_PRECONDITION_NOT_SATISFIED should not be enabled by default.
- #7882 wrong exception text from condition_variable::wait(unique_lock<mutex>&).

## Version 3.1.0 - boost 1.52

Deprecated Features:

Deprecated features since boost 1.50 available only until boost 1.55:

These deprecated features will be provided by default up to boost 1.52. If you don't want to include the deprecated features you could define BOOST_THREAD_DONT_PROVIDE_DEPRECATED_FEATURES_SINCE_V3_0_0. Since 1.53 these features will not be included any more by default. Since this version, if you want to include the deprecated features yet you could define BOOST_THREAD_PROVIDE_DEPRECATED_FEATURES_SINCE_V3_0_0. These deprecated features will be only available until boost 1.55, that is you have yet 1 year to move to the new features.

- Time related functions don't using the Boost.Chrono library, use the chrono overloads instead.

Breaking changes when BOOST_THREAD_VERSION==3 (Default value since Boost 1.53):

There are some new features which share the same interface but with different behavior. These breaking features are provided by default when BOOST_THREAD_VERSION is 3, but the user can however choose the version 2 behavior by defining the corresponding macro. As for the deprecated features, these broken features will be only available until boost 1.55.

- #6229 Rename the unique_future to future following the c++11.
- #6266 Breaking change: thread destructor should call terminate if joinable.
- #6269 Breaking change: thread move assignment should call terminate if joinable.

New Features:

- #2361 thread_specific_ptr: document nature of the key, complexity and rationale.
- #4710 C++11 compliance: Missing async().
- #7283 C++11 compliance: Add notify_all_at_thread_exit.
- #7345 C++11 compliance: Add noexcept to recursive mutex try_lock.

Fixed Bugs:

- #2797 Two problems with thread_specific_ptr.
- #5274 failed to compile future.hpp with stlport 5.1.5 under msvc8.1, because of undefined class.
- #5431 compile error in Windows CE 6.0(interlocked).
- #5696 win32 detail::set_tss_data does nothing when tss_cleanup_function is NULL.
- #6931 mutex waits forwever with Intel C++ Compiler XE 12.1.5.344 Build 20120612
- #7045 Thread library does not automatically compile date_time.
- #7173 wrong function name interrupt_point().
- #7200 Unable to build boost.thread modularized.
- #7220 gcc 4.6.2 warns about inline+dllimport functions.
- #7238 this_thread::sleep_for() does not respond to interrupt().
- #7245 Minor typos on documentation related to version 3.
- #7272 win32/thread_primitives.hpp: (Unneccessary) Warning.
- #7284 Clarify that there is no access priority between lock and shared_lock on shared mutex.
- #7329 boost/thread/future.hpp does not compile on HPUX.
- #7336 BOOST_THREAD_DONT_USE_SYSTEM doesn't work.
- #7349 packaged_task holds reference to temporary.
- #7350 allocator_destructor does not destroy object
- #7360 Memory leak in pthread implementation of boost::thread_specific_ptr
- #7370 Boost.Thread documentation
- #7438 Segmentation fault in test_once regression test in group.join_all();
- #7461 detail::win32::ReleaseSemaphore may be called with count_to_release equal to 0
- #7499 call_once doesn't call even once

## Version 3.0.1 - boost 1.51

Deprecated Features:

Deprecated features since boost 1.50 available only until boost 1.55:

These deprecated features will be provided by default up to boost 1.52. If you don't want to include the deprecated features you could define BOOST_THREAD_DONT_PROVIDE_DEPRECATED_FEATURES_SINCE_V3_0_0. Since 1.53 these features will not be included any more by default. Since this version, if you want to include the deprecated features yet you could define BOOST_THREAD_PROVIDE_DEPRECATED_FEATURES_SINCE_V3_0_0. These deprecated features will be only available until boost 1.55, that is you have 1 year and a half to move to the new features.

- Time related functions don't using the Boost.Chrono library, use the chrono overloads instead.

Breaking changes when BOOST_THREAD_VERSION==3:

There are some new features which share the same interface but with different behavior. These breaking features are provided by default when BOOST_THREAD_VERSION is 3, but the user can however choose the version 2 behavior by defining the corresponding macro. As for the deprecated features, these broken features will be only available until boost 1.55.

- #6229 Rename the unique_future to future following the c++11.
- #6266 Breaking change: thread destructor should call terminate if joinable.
- #6269 Breaking change: thread move assignment should call terminate if joinable.

Fixed Bugs:

- #4258 Linking with boost thread does not work on mingw/gcc 4.5.
- #4885 Access violation in set_tss_data at process exit due to invalid assumption about TlsAlloc.
- #6931 mutex waits forwever with Intel Compiler and /debug:parallel
- #7044 boost 1.50.0 header missing.
- #7052 Thread: BOOST_THREAD_PROVIDES_DEPRECATED_FEATURES_SINCE_V3_0_0 only masks thread::operator==, thread::operator!= forward declarations, not definitions.
- #7066 An attempt to fix current_thread_tls_key static initialization order.
- #7074 Multiply defined symbol boost::allocator_arg.
- #7078 Trivial 64-bit warning fix on Windows for thread attribute stack size
- #7089 BOOST_THREAD_WAIT_BUG limits functionality without solving anything

## Version 3.0.0 - boost 1.50

Breaking changes when BOOST_THREAD_VERSION==3:

- #6229 Breaking change: Rename the unique_future to future following the c++11.
- #6266 Breaking change: thread destructor should call terminate if joinable.
- #6269 Breaking change: thread move assignment should call terminate if joinable.

New Features:

- #1850 Request for unlock_guard to compliment lock_guard.
- #2637 Request for shared_mutex duration timed_lock and timed_lock_shared.
- #2741 Proposal to manage portable and non portable thread attributes.
- #3567 Request for shared_lock_guard.
- #6194 Adapt to Boost.Move.
- #6195 c++11 compliance: Provide the standard time related interface using Boost.Chrono.

- #6217 Enhance Boost.Thread shared mutex interface following Howard Hinnant proposal.
- #6224 c++11 compliance: Add the use of standard noexcept on compilers supporting them.
- #6225 Add the use of standard =delete defaulted operations on compilers supporting them.
- #6226 c++11 compliance: Add explicit bool conversion from locks.
- #6228 Add promise constructor with allocator following the standard c++11.
- #6230 c++11 compliance: Follows the exception reporting mechanism as defined in the c++11.
- #6231 Add BasicLockable requirements in the documentation to follow c++11.
- #6272 c++11 compliance: Add thread::id hash specialization.
- #6273 c++11 compliance: Add cv_status enum class and use it on the conditions wait functions.
- #6342 c++11 compliance: Adapt the one_flag to the c++11 interface.
- #6671 upgrade_lock: missing mutex and release functions.
- #6672 upgrade_lock:: missing constructors from time related types.
- #6675 upgrade_lock:: missing non-member swap.
- #6676 lock conversion should be explicit.
- Added missing packaged_task::result_type and packaged_task:: constructor with allocator.
- Added packaged_task::reset()

Fixed Bugs:

- #2380 boost::move from lvalue does not work with gcc.
- #2430 shared_mutex for win32 doesn't have timed_lock_upgrade.
- #2575 Bug- Boost 1.36.0 on Itanium platform.
- #3160 Duplicate tutorial code in boost::thread.
- #4345 thread::id and joining problem with cascade of threads.
- #4521 Error using boost::move on packaged_task (MSVC 10).
- #4711 Must use implementation details to return move-only types.
- #4921 BOOST_THREAD_USE_DLL and BOOST_THREAD_USE_LIB are crucial and need to be documented.
- #5013 documentation: boost::thread: pthreas_exit causes terminate().
- #5173 boost::this_thread::get_id is very slow.
- #5351 interrupt a future get boost::unknown_exception.
- #5516 Upgrade lock is not acquired when previous upgrade lock releases if another read lock is present.
- #5990 shared_future<T>::get() has wrong return type.
- #6174 packaged_task doesn't correctly handle moving results.
- #6222 Compile error with SunStudio: unique_future move.

- #6354 PGI: Compiler threading support is not turned on.
- #6673 shared_lock: move assign doesn't works with c++11.
- #6674 shared_mutex: try_lock_upgrade_until doesn't works.
- #6908 Compile error due to unprotected definitions of _WIN32_WINNT and WINVER.
- #6940 TIME_UTC is a macro in C11.
- #6959 call of abs is ambiguous.
- Fix issue signaled on the ML with task_object(task_object const&) in presence of task_object(task_object &&)

## Version 2.1.1 - boost 1.49

Fixed Bugs:

- #2309 Lack of g++ symbol visibility support in Boost.Thread.
- #2639 documentation should be extended(defer_lock, try_to_lock, ...).
- #3639 Boost.Thread doesn't build with Sun-5.9 on Linux.
- #3762 Thread can't be compiled with winscw (Codewarrior by Nokia).
- #3885 document about mix usage of boost.thread and native thread api.
- #3975 Incorrect precondition for promise::set_wait_callback().
- #4048 thread::id formatting involves locale
- #4315 gcc 4.4 Warning: inline ... declared as dllimport: attribute ignored.
- #4480 OpenVMS patches for compiler issues workarounds.
- #4819 boost.thread's documentation misprints.
- #5423 thread issues with C++0x.
- #5617 boost::thread::id copy ctor.
- #5739 set-but-not-used warnings with gcc-4.6.
- #5826 threads.cpp: resource leak on threads creation failure.
- #5839 thread.cpp: ThreadProxy leaks on exceptions.
- #5859 win32 shared_mutex constructor leaks on exceptions.
- #6100 Compute hardware_concurrency() using get_nprocs() on GLIBC systems.
- #6168 recursive_mutex is using wrong config symbol (possible typo).
- #6175 Compile error with SunStudio.
- #6200 patch to have condition_variable and mutex error better handle EINTR.
- #6207 shared_lock swap compiler error on clang 3.0 c++11.
- #6208 try_lock_wrapper swap compiler error on clang 3.0 c++11.

## Version 2.1.0 - Changes since boost 1.40

The 1.41.0 release of Boost adds futures to the thread library. There are also a few minor changes.

## Changes since boost 1.35

The 1.36.0 release of Boost includes a few new features in the thread library:

- New generic `lock()` and `try_lock()` functions for locking multiple mutexes at once.
- Rvalue reference support for move semantics where the compilers supports it.
- A few bugs fixed and missing functions added (including the serious win32 condition variable bug).
- `scoped_try_lock` types are now backwards-compatible with Boost 1.34.0 and previous releases.
- Support for passing function arguments to the thread function by supplying additional arguments to the `boost::thread` constructor.
- Backwards-compatibility overloads added for `timed_lock` and `timed_wait` functions to allow use of `xtime` for timeouts.

## Version 2.0.0 - Changes since boost 1.34

Almost every line of code in **Boost.Thread** has been changed since the 1.34 release of boost. However, most of the interface changes have been extensions, so the new code is largely backwards-compatible with the old code. The new features and breaking changes are described below.

## New Features

- Instances of `boost::thread` and of the various lock types are now movable.
- Threads can be interrupted at *interruption points*.
- Condition variables can now be used with any type that implements the `Lockable` concept, through the use of `boost::condition_variable_any` (`boost::condition` is a `typedef` to `boost::condition_variable_any`, provided for backwards compatibility). `boost::condition_variable` is provided as an optimization, and will only work with `boost::unique_lock<boost::mutex>` (`boost::mutex::scoped_lock`).
- Thread IDs are separated from `boost::thread`, so a thread can obtain it's own ID (using `boost::this_thread::get_id()`), and IDs can be used as keys in associative containers, as they have the full set of comparison operators.
- Timeouts are now implemented using the Boost DateTime library, through a typedef `boost::system_time` for absolute timeouts, and with support for relative timeouts in many cases. `boost::xtime` is supported for backwards compatibility only.
- Locks are implemented as publicly accessible templates `boost::lock_guard`, `boost::unique_lock`, `boost::shared_lock`, and `boost::upgrade_lock`, which are templated on the type of the mutex. The `Lockable` concept has been extended to include publicly available `lock()` and `unlock()` member functions, which are used by the lock types.

## Breaking Changes

The list below should cover all changes to the public interface which break backwards compatibility.

- `boost::try_mutex` has been removed, and the functionality subsumed into `boost::mutex`. `boost::try_mutex` is left as a `typedef`, but is no longer a separate class.
- `boost::recursive_try_mutex` has been removed, and the functionality subsumed into `boost::recursive_mutex`. `boost::recursive_try_mutex` is left as a `typedef`, but is no longer a separate class.

- `boost::detail::thread::lock_ops` has been removed. Code that relies on the `lock_ops` implementation detail will no longer work, as this has been removed, as it is no longer necessary now that mutex types now have public `lock()` and `unlock()` member functions.
- `scoped_lock` constructors with a second parameter of type `bool` are no longer provided. With previous boost releases,

  ```
  boost::mutex::scoped_lock some_lock(some_mutex,false);
  ```

  could be used to create a lock object that was associated with a mutex, but did not lock it on construction. This facility has now been replaced with the constructor that takes a `boost::defer_lock_type` as the second parameter:

  ```
  boost::mutex::scoped_lock some_lock(some_mutex,boost::defer_lock);
  ```

- The `locked()` member function of the `scoped_lock` types has been renamed to `owns_lock()`.
- You can no longer obtain a `boost::thread` instance representing the current thread: a default-constructed `boost::thread` object is not associated with any thread. The only use for such a thread object was to support the comparison operators: this functionality has been moved to `boost::thread::id`.
- The broken `boost::read_write_mutex` has been replaced with `boost::shared_mutex`.
- `boost::mutex` is now never recursive. For Boost releases prior to 1.35 `boost::mutex` was recursive on Windows and not on POSIX platforms.
- When using a `boost::recursive_mutex` with a call to `boost::condition_variable_any::wait()`, the mutex is only unlocked one level, and not completely. This prior behaviour was not guaranteed and did not feature in the tests.

# Future

The following features will be included in next releases.

1. Complete the C++11 missing features, in particular
   - #7285 C++11 compliance: Allow to pass movable arguments for call_once.
   - #6227 C++11 compliance: Use of variadic templates on Generic Locking Algorithms on compilers providing them.
2. Add some of the extension proposed in A Standardized Representation of Asynchronous Operations, in particular
   - #7589 Synchro: Add polymorphic lockables.
   - #7449 Synchro: Add a synchronized value class.
   - #7445 Async: Add future<>.then.
   - #7446 Async: Add when_any.
   - #7447 Async: Add when_all.
   - #7448 Async: Add async taking a scheduler parameter.

# Thread Management

## Synopsis

```
#include <boost/thread/thread.hpp>

namespace boost
{
  class thread;
  void swap(thread& lhs,thread& rhs) noexcept;

  namespace this_thread
  {
    thread::id get_id() noexcept;
    template<typename TimeDuration>
    void yield() noexcept; // DEPRECATED
    template <class Clock, class Duration>
    void sleep_until(const chrono::time_point<Clock, Duration>& abs_time);
    template <class Rep, class Period>
    void sleep_for(const chrono::duration<Rep, Period>& rel_time);

    template<typename Callable>
    void at_thread_exit(Callable func); // EXTENSION

    void interruption_point(); // EXTENSION
    bool interruption_requested() noexcept; // EXTENSION
    bool interruption_enabled() noexcept; // EXTENSION
    class disable_interruption; // EXTENSION
    class restore_interruption; // EXTENSION

  #if defined BOOST_THREAD_USES_DATETIME
    template <TimeDuration>
    void sleep(TimeDuration const& rel_time);  // DEPRECATED
    void sleep(system_time const& abs_time); // DEPRECATED
  #endif
  }
  class thread_group; // EXTENSION

}
```

## Tutorial

The `boost::thread` class is responsible for launching and managing threads. Each `boost::thread` object represents a single thread of execution, or *Not-a-Thread*, and at most one `boost::thread` object represents a given thread of execution: objects of type `boost::thread` are not copyable.

Objects of type `boost::thread` are movable, however, so they can be stored in move-aware containers, and returned from functions. This allows the details of thread creation to be wrapped in a function.

```
boost::thread make_thread();

void f()
{
    boost::thread some_thread=make_thread();
    some_thread.join();
}
```

**Note**

On compilers that support rvalue references, `boost::thread` provides a proper move constructor and move-assignment operator, and therefore meets the C++0x *MoveConstructible* and *MoveAssignable* concepts. With such compilers, `boost::thread` can therefore be used with containers that support those concepts.

For other compilers, move support is provided with a move emulation layer, so containers must explicitly detect that move emulation layer. See <boost/thread/detail/move.hpp> for details.

## Launching threads

A new thread is launched by passing an object of a callable type that can be invoked with no parameters to the constructor. The object is then copied into internal storage, and invoked on the newly-created thread of execution. If the object must not (or cannot) be copied, then `boost::ref` can be used to pass in a reference to the function object. In this case, the user of **Boost.Thread** must ensure that the referred-to object outlives the newly-created thread of execution.

```
struct callable
{
    void operator()();
};

boost::thread copies_are_safe()
{
    callable x;
    return boost::thread(x);
} // x is destroyed, but the newly-created thread has a copy, so this is OK

boost::thread oops()
{
    callable x;
    return boost::thread(boost::ref(x));
} // x is destroyed, but the newly-created thread still has a reference
  // this leads to undefined behaviour
```

If you wish to construct an instance of `boost::thread` with a function or callable object that requires arguments to be supplied, this can be done by passing additional arguments to the `boost::thread` constructor:

```
void find_the_question(int the_answer);

boost::thread deep_thought_2(find_the_question,42);
```

The arguments are *copied* into the internal thread structure: if a reference is required, use `boost::ref`, just as for references to callable functions.

There is an unspecified limit on the number of additional arguments that can be passed.

## Thread attributes

Thread launched in this way are created with implementation defined thread attributes as stack size, scheduling, priority, ... or any platform specific attributes. It is not evident how to provide a portable interface that allows the user to set the platform specific attributes. Boost.Thread stay in the middle road through the class thread::attributes which allows to set at least in a portable way the stack size as follows:

```
boost::thread::attributes attrs;
attrs.set_size(4096*10);
boost::thread deep_thought_2(attrs, find_the_question, 42);
```

Even for this simple attribute there could be portable issues as some platforms could require that the stack size should have a minimal size and/or be a multiple of a given page size. The library adapts the requested size to the platform constraints so that the user doesn't need to take care of it.

This is the single attribute that is provided in a portable way. In order to set any other thread attribute at construction time the user needs to use non portable code.

On PThread platforms the user will need to get the thread attributes handle and use it for whatever attribute.

Next follows how the user could set the stack size and the scheduling policy on PThread platforms.

```
boost::thread::attributes attrs;
// set portable attributes
// ...
attr.set_stack_size(4096*10);
#if defined(BOOST_THREAD_PLATFORM_WIN32)
    // ... window version
#elif defined(BOOST_THREAD_PLATFORM_PTHREAD)
    // ... pthread version
    pthread_attr_setschedpolicy(attr.get_native_handle(), SCHED_RR);
#else
#error "Boost threads unavailable on this platform"
#endif
boost::thread th(attrs, find_the_question, 42);
```

On Windows platforms it is not so simple as there is no type that compiles the thread attributes. There is a linked to the creation of a thread on Windows that is emulated via the thread::attributes class. This is the LPSECURITY_ATTRIBUTES lpThreadAttributes. Boost.Thread provides a non portable set_security function so that the user can provide it before the thread creation as follows

```
#if defined(BOOST_THREAD_PLATFORM_WIN32)
  boost::thread::attributes attrs;
  // set portable attributes
  attr.set_stack_size(4096*10);
  // set non portable attribute
  LPSECURITY_ATTRIBUTES sec;
  // init sec
  attr.set_security(sec);
  boost::thread th(attrs, find_the_question, 42);
  // Set other thread attributes using the native_handle_type.
  //...
#else
#error "Platform not supported"
#endif
```

## Exceptions in thread functions

If the function or callable object passed to the `boost::thread` constructor propagates an exception when invoked that is not of type `boost::thread_interrupted`, `std::terminate()` is called.

## Detaching thread

A thread can be detached by explicitly invoking the `detach()` member function on the `boost::thread` object. In this case, the `boost::thread` object ceases to represent the now-detached thread, and instead represents *Not-a-Thread*.

```
int main()
{
  boost::thread t(my_func);
  t.detach();
}
```

## Joining a thread

In order to wait for a thread of execution to finish, the `join()`, __join_for or __join_until ( `timed_join()` deprecated) member functions of the `boost::thread` object must be used. `join()` will block the calling thread until the thread represented by the `boost::thread` object has completed.

```
int main()
{
  boost::thread t(my_func);
  t.join();
}
```

If the thread of execution represented by the `boost::thread` object has already completed, or the `boost::thread` object represents *Not-a-Thread*, then `join()` returns immediately.

```
int main()
{
  boost::thread t;
  t.join(); // do nothing
}
```

Timed based join are similar, except that a call to __join_for or __join_until will also return if the thread being waited for does not complete when the specified time has elapsed or reached respectively.

```
int main()
{
  boost::thread t;
  if ( t.join_for(boost::chrono::milliseconds(500)) )
    // do something else
  t.join(); // join anyway
}
```

## Destructor V1

When the `boost::thread` object that represents a thread of execution is destroyed the thread becomes *detached*. Once a thread is detached, it will continue executing until the invocation of the function or callable object supplied on construction has completed, or the program is terminated. A thread can also be detached by explicitly invoking the `detach()` member function on the `boost::thread` object. In this case, the `boost::thread` object ceases to represent the now-detached thread, and instead represents *Not-a-Thread*.

## Destructor V2

When the `boost::thread` object that represents a thread of execution is destroyed the program terminates if the thread is __joinable__.

```
int main()
{
  boost::thread t(my_func);
} // calls std::terminate()
```

You can use a thread_joiner to ensure that the thread has been joined at the thread destructor.

```
int main()
{
  boost::thread t(my_func);
  boost::thread_joiner g(t);
  // do someting else
} // here the thread_joiner destructor will join the thread before it is destroyed.
```

## Interruption

A running thread can be *interrupted* by invoking the `interrupt()` member function of the corresponding `boost::thread` object. When the interrupted thread next executes one of the specified *interruption points* (or if it is currently *blocked* whilst executing one) with interruption enabled, then a `boost::thread_interrupted` exception will be thrown in the interrupted thread. If not caught, this will cause the execution of the interrupted thread to terminate. As with any other exception, the stack will be unwound, and destructors for objects of automatic storage duration will be executed.

If a thread wishes to avoid being interrupted, it can create an instance of `boost::this_thread::disable_interruption`. Objects of this class disable interruption for the thread that created them on construction, and restore the interruption state to whatever it was before on destruction:

```
void f()
{
    // interruption enabled here
    {
        boost::this_thread::disable_interruption di;
        // interruption disabled
        {
            boost::this_thread::disable_interruption di2;
            // interruption still disabled
        } // di2 destroyed, interruption state restored
        // interruption still disabled
    } // di destroyed, interruption state restored
    // interruption now enabled
}
```

The effects of an instance of `boost::this_thread::disable_interruption` can be temporarily reversed by constructing an instance of `boost::this_thread::restore_interruption`, passing in the `boost::this_thread::disable_interruption` object in question. This will restore the interruption state to what it was when the `boost::this_thread::disable_interruption` object was constructed, and then disable interruption again when the `boost::this_thread::restore_interruption` object is destroyed.

```
void g()
{
    // interruption enabled here
    {
        boost::this_thread::disable_interruption di;
        // interruption disabled
        {
            boost::this_thread::restore_interruption ri(di);
            // interruption now enabled
        } // ri destroyed, interruption disable again
    } // di destroyed, interruption state restored
    // interruption now enabled
}
```

At any point, the interruption state for the current thread can be queried by calling `boost::this_thread::interruption_enabled()`.

### Predefined Interruption Points

The following functions are *interruption points*, which will throw `boost::thread_interrupted` if interruption is enabled for the current thread, and interruption is requested for the current thread:

- `boost::thread::join()`
- `boost::thread::timed_join()`
- `boost::thread::try_join_for()`,
- `boost::thread::try_join_until()`,
- `boost::condition_variable::wait()`
- `boost::condition_variable::timed_wait()`
- `boost::condition_variable::wait_for()`
- `boost::condition_variable::wait_until()`
- `boost::condition_variable_any::wait()`
- `boost::condition_variable_any::timed_wait()`
- `boost::condition_variable_any::wait_for()`
- `boost::condition_variable_any::wait_until()`
- `boost::thread::sleep()`
- `boost::this_thread::sleep_for()`
- `boost::this_thread::sleep_until()`
- `boost::this_thread::interruption_point()`

## Thread IDs

Objects of class `boost::thread::id` can be used to identify threads. Each running thread of execution has a unique ID obtainable from the corresponding `boost::thread` by calling the `get_id()` member function, or by calling `boost::this_thread::get_id()` from within the thread. Objects of class `boost::thread::id` can be copied, and used as keys in associative containers: the full range of comparison operators is provided. Thread IDs can also be written to an output stream using the stream insertion operator, though the output format is unspecified.

Each instance of `boost::thread::id` either refers to some thread, or *Not-a-Thread*. Instances that refer to *Not-a-Thread* compare equal to each other, but not equal to any instances that refer to an actual thread of execution. The comparison operators on `boost::thread::id` yield a total order for every non-equal thread ID.

## Using native interfaces with Boost.Thread resources

`boost::thread` class has members `native_handle_type` and `native_handle` providing access to the underlying native handle.

This native handle can be used to change for example the scheduling.

In general, it is not safe to use this handle with operations that can conflict with the ones provided by Boost.Thread. An example of bad usage could be detaching a thread directly as it will not change the internals of the `boost::thread` instance, so for example the joinable function will continue to return true, while the native thread is no more joinable.

```
thread t(fct);
thread::native_handle_type hnd=t.native_handle();
pthread_detach(hnd);
assert(t.joinable());
```

## Using Boost.Thread interfaces in a native thread

Any thread of execution created using the native interface is called a native thread in this documentation.

The first example of a native thread of execution is the main thread.

The user can access to some synchronization functions related to the native current thread using the `boost::this_thread` `yield`, `sleep`, `sleep_for`, `sleep_until`, functions.

```
int main() {
  // ...
  boost::this_thread::sleep_for(boost::chrono::milliseconds(10));
  // ...
}
```

Of course all the synchronization facilities provided by Boost.Thread are also available on native threads.

The `boost::this_thread` interrupt related functions behave in a degraded mode when called from a thread created using the native interface, i.e. `boost::this_thread::interruption_enabled()` returns false. As consequence the use of `boost::this_thread::disable_interruption` and `boost::this_thread::restore_interruption` will do nothing and calls to `boost::this_thread::interruption_point()` will be just ignored.

As the single way to interrupt a thread is through a `boost::thread` instance, `interruption_request()` wiil returns false for the native threads.

### `pthread_exit` POSIX limitation

`pthread_exit` in glibc/NPTL causes a "forced unwind" that is almost like a C++ exception, but not quite. On Mac OS X, for example, `pthread_exit` unwinds without calling C++ destructors.

This behavior is incompatible with the current Boost.Thread design, so the use of this function in a POSIX thread result in undefined behavior of any Boost.Thread function.

# Class `thread`

```
#include <boost/thread/thread.hpp>

class thread
{
public:
    class attributes; // EXTENSION

    thread() noexcept;
    thread(const thread&) = delete;
    thread& operator=(const thread&) = delete;

    thread(thread&&) noexcept;
    thread& operator=(thread&&) noexcept;
    ~thread();

    template <class F>
    explicit thread(F f);
    template <class F>
    thread(F &&f);

    template <class F,class A1,class A2,...>
    thread(F f,A1 a1,A2 a2,...);
    template <class F, class ...Args>
    explicit thread(F&& f, Args&&... args);

    template <class F>
    explicit thread(attributes& attrs, F f); // EXTENSION
    template <class F>
    thread(attributes& attrs, F &&f); // EXTENSION
    template <class F, class ...Args>
    explicit thread(attributes& attrs, F&& f, Args&&... args);

    // move support
    thread(thread && x) noexcept;
    thread& operator=(thread && x) noexcept;

    void swap(thread& x) noexcept;

    class id;

    id get_id() const noexcept;

    bool joinable() const noexcept;
    void join();
    template <class Rep, class Period>
    bool try_join_for(const chrono::duration<Rep, Period>& rel_time); // EXTENSION
    template <class Clock, class Duration>
    bool try_join_until(const chrono::time_point<Clock, Duration>& t); // EXTENSION

    void detach();

    static unsigned hardware_concurrency() noexcept;

    typedef platform-specific-type native_handle_type;
    native_handle_type native_handle();

    void interrupt(); // EXTENSION
    bool interruption_requested() const noexcept; // EXTENSION
```

```
#if defined BOOST_THREAD_USES_DATETIME
    bool timed_join(const system_time& wait_until); // DEPRECATED
    template<typename TimeDuration>
    bool timed_join(TimeDuration const& rel_time); // DEPRECATED
    static void sleep(const system_time& xt);// DEPRECATED
#endif

#if defined BOOST_THREAD_PROVIDES_THREAD_EQ
    bool operator==(const thread& other) const; // DEPRECATED
    bool operator!=(const thread& other) const; // DEPRECATED

#endif
    static void yield() noexcept; // DEPRECATED

};

void swap(thread& lhs,thread& rhs) noexcept;
```

## Default Constructor

```
thread() noexcept;
```

Effects: Constructs a `boost::thread` instance that refers to *Not-a-Thread*.

Postconditions: `this->get_id()==thread::id()`

Throws: Nothing

## Move Constructor

```
thread(thread&& other) noexcept;
```

Effects: Transfers ownership of the thread managed by `other` (if any) to the newly constructed `boost::thread` instance.

Postconditions: `other.get_id()==thread::id()` and `get_id()` returns the value of `other.get_id()` prior to the construction

Throws: Nothing

## Move assignment operator

```
thread& operator=(thread&& other) noexcept;
```

### Warning

DEPRECATED since 3.0.0: BOOST_THREAD_DONT_PROVIDE_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE behavior.

Available only up to Boost 1.56.

Join the thread before moving.

Effects: Transfers ownership of the thread managed by `other` (if any) to `*this`.

- if defined BOOST_THREAD_DONT_PROVIDE_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE: If there was a thread previously associated with `*this` then that thread is detached, DEPRECATED

- if defined BOOST_THREAD_PROVIDES_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE: If the thread is joinable calls to std::terminate.

Postconditions: `other->get_id()==thread::id()` and `get_id()` returns the value of `other.get_id()` prior to the assignment.

Throws: Nothing

## Thread Constructor

```
template<typename Callable>
thread(Callable func);
```

Requires: `Callable` must by Copyable and `func()` must be a valid expression.

Effects: `func` is copied into storage managed internally by the thread library, and that copy is invoked on a newly-created thread of execution. If this invocation results in an exception being propagated into the internals of the thread library that is not of type `boost::thread_interrupted`, then `std::terminate()` will be called. Any return value from this invocation is ignored.

Postconditions: `*this` refers to the newly created thread of execution and `this->get_id()!=thread::id()`.

Throws: `boost::thread_resource_error` if an error occurs.

Error Conditions: **resource_unavailable_try_again** : the system lacked the necessary resources to create an- other thread, or the system-imposed limit on the number of threads in a process would be exceeded.

## Thread Attributes Constructor EXTENSION

```
template<typename Callable>
thread(attributes& attrs, Callable func);
```

Preconditions: `Callable` must by copyable.

Effects: `func` is copied into storage managed internally by the thread library, and that copy is invoked on a newly-created thread of execution with the specified attributes. If this invocation results in an exception being propagated into the internals of the thread library that is not of type `boost::thread_interrupted`, then `std::terminate()` will be called. Any return value from this invocation is ignored. If the attributes declare the native thread as detached, the boost::thread will be detached.

Postconditions: `*this` refers to the newly created thread of execution and `this->get_id()!=thread::id()`.

Throws: `boost::thread_resource_error` if an error occurs.

Error Conditions: **resource_unavailable_try_again** : the system lacked the necessary resources to create an- other thread, or the system-imposed limit on the number of threads in a process would be exceeded.

## Thread Callable Move Constructor

```
template<typename Callable>
thread(Callable &&func);
```

Preconditions: `Callable` must by Movable.

Effects: `func` is moved into storage managed internally by the thread library, and that copy is invoked on a newly-created thread of execution. If this invocation results in an exception being propagated into the internals of the thread library that is not of type `boost::thread_interrupted`, then `std::terminate()` will be called. Any return value from this invocation is ignored.

Postconditions: `*this` refers to the newly created thread of execution and `this->get_id()!=thread::id()`.

Throws: `boost::thread_resource_error` if an error occurs.

Error Conditions: **resource_unavailable_try_again** : the system lacked the necessary resources to create an- other thread, or the system-imposed limit on the number of threads in a process would be exceeded.

## Thread Attributes Move Constructor EXTENSION

```
template<typename Callable>
thread(attributes& attrs, Callable func);
```

Preconditions: `Callable` must by copyable.

Effects: `func` is copied into storage managed internally by the thread library, and that copy is invoked on a newly-created thread of execution with the specified attributes. If this invocation results in an exception being propagated into the internals of the thread library that is not of type `boost::thread_interrupted`, then `std::terminate()` will be called. Any return value from this invocation is ignored. If the attributes declare the native thread as detached, the boost::thread will be detached.

Postconditions: `*this` refers to the newly created thread of execution and `this->get_id()!=thread::id()`.

Throws: `boost::thread_resource_error` if an error occurs.

Error Conditions: **resource_unavailable_try_again** : the system lacked the necessary resources to create an- other thread, or the system-imposed limit on the number of threads in a process would be exceeded.

## Thread Constructor with arguments

```
template <class F,class A1,class A2,...>
thread(F f,A1 a1,A2 a2,...);
```

Preconditions: `F` and each `A`n must by copyable or movable.

Effects: As if `thread(boost::bind(f,a1,a2,...))`. Consequently, `f` and each `a`n are copied into internal storage for access by the new thread.

Postconditions: `*this` refers to the newly created thread of execution.

Throws: `boost::thread_resource_error` if an error occurs.

Error Conditions: **resource_unavailable_try_again** : the system lacked the necessary resources to create an- other thread, or the system-imposed limit on the number of threads in a process would be exceeded.

Note: Currently up to nine additional arguments `a1` to `a9` can be specified in addition to the function `f`.

## Thread Destructor

```
~thread();
```

> **Warning**
>
> DEPRECATED since 3.0.0: BOOST_THREAD_DONT_PROVIDE_THREAD_DESTRUCTOR_CALLS_TERMINATE_IF_JOINABLE behavior.
>
> Available only up to Boost 1.56.
>
> Join the thread before destroying or use a scoped thread.

Effects: - if defined BOOST_THREAD_DONT_PROVIDE_THREAD_DESTRUCTOR_CALLS_TERMINATE_IF_JOINABLE: If `*this` has an associated thread of execution, calls `detach()`, DEPRECATED

- BOOST_THREAD_PROVIDES_THREAD_DESTRUCTOR_CALLS_TERMINATE_IF_JOINABLE: If the thread is joinable calls to std::terminate. Destroys `*this`.

Throws: Nothing.

Note: Either implicitly detaching or joining a `joinable()` thread in its destructor could result in difficult to debug correctness (for `detach`) or performance (for `join`) bugs encountered only when an exception is raised. Thus the programmer must ensure that the destructor is never executed while the thread is still joinable.

## Member function `joinable()`

```
bool joinable() const noexcept;
```

Returns: `true` if `*this` refers to a thread of execution, `false` otherwise.

Throws: Nothing

## Member function `join()`

```
void join();
```

Preconditions: the thread is joinable.

Effects: If `*this` refers to a thread of execution, waits for that thread of execution to complete.

Synchronization: The completion of the thread represented by `*this` synchronizes with the corresponding successful `join()` return.

Note: Operations on *this are not synchronized.

Postconditions: If `*this` refers to a thread of execution on entry, that thread of execution has completed. `*this` no longer refers to any thread of execution.

Throws: `boost::thread_interrupted` if the current thread of execution is interrupted or `system_error`

Error Conditions: **resource_deadlock_would_occur**: if deadlock is detected or `this->get_id() == boost::this_thread::get_id()`.

**invalid_argument**: if the thread is not joinable and `BOOST_THREAD_TRHOW_IF_PRECONDITION_NOT_SATISFIED` is defined.

Notes: `join()` is one of the predefined *interruption points*.

## Member function `timed_join()` DEPRECATED

```
bool timed_join(const system_time& wait_until);

template<typename TimeDuration>
bool timed_join(TimeDuration const& rel_time);
```

### Warning

DEPRECATED since 3.00.

Available only up to Boost 1.56.

Use instead `try_join_for`, `try_join_until`.

Preconditions: the thread is joinable.

Effects: If `*this` refers to a thread of execution, waits for that thread of execution to complete, the time `wait_until` has been reach or the specified duration `rel_time` has elapsed. If `*this` doesn't refer to a thread of execution, returns immediately.

Returns: `true` if `*this` refers to a thread of execution on entry, and that thread of execution has completed before the call times out, `false` otherwise.

Postconditions: If `*this` refers to a thread of execution on entry, and `timed_join` returns `true`, that thread of execution has completed, and `*this` no longer refers to any thread of execution. If this call to `timed_join` returns `false`, `*this` is unchanged.

Throws: `boost::thread_interrupted` if the current thread of execution is interrupted or `system_error`

Error Conditions: **resource_deadlock_would_occur**: if deadlock is detected or this->get_id() == boost::this_thread::get_id().

**invalid_argument**: if the thread is not joinable and BOOST_THREAD_TRHOW_IF_PRECONDITION_NOT_SATISFIED is defined.

Notes: `timed_join()` is one of the predefined *interruption points*.

## Member function `try_join_for()` EXTENSION

```
template <class Rep, class Period>
bool try_join_for(const chrono::duration<Rep, Period>& rel_time);
```

Preconditions: the thread is joinable.

Effects: If `*this` refers to a thread of execution, waits for that thread of execution to complete, the specified duration `rel_time` has elapsed. If `*this` doesn't refer to a thread of execution, returns immediately.

Returns: `true` if `*this` refers to a thread of execution on entry, and that thread of execution has completed before the call times out, `false` otherwise.

Postconditions: If `*this` refers to a thread of execution on entry, and `try_join_for` returns `true`, that thread of execution has completed, and `*this` no longer refers to any thread of execution. If this call to `try_join_for` returns `false`, `*this` is unchanged.

Throws: `boost::thread_interrupted` if the current thread of execution is interrupted or `system_error`

Error Conditions: **resource_deadlock_would_occur**: if deadlock is detected or this->get_id() == boost::this_thread::get_id().

**invalid_argument**: if the thread is not joinable and BOOST_THREAD_TRHOW_IF_PRECONDITION_NOT_SATISFIED is defined.

Notes: `try_join_for()` is one of the predefined *interruption points*.

## Member function `try_join_until()` EXTENSION

```
template <class Clock, class Duration>
bool try_join_until(const chrono::time_point<Clock, Duration>& abs_time);
```

Preconditions: the thread is joinable.

Effects: If `*this` refers to a thread of execution, waits for that thread of execution to complete, the time `abs_time` has been reach. If `*this` doesn't refer to a thread of execution, returns immediately.

Returns: `true` if `*this` refers to a thread of execution on entry, and that thread of execution has completed before the call times out, `false` otherwise.

Postconditions: If `*this` refers to a thread of execution on entry, and `try_join_until` returns `true`, that thread of execution has completed, and `*this` no longer refers to any thread of execution. If this call to `try_join_until` returns `false`, `*this` is unchanged.

Throws: `boost::thread_interrupted` if the current thread of execution is interrupted or `system_error`

Error Conditions: **resource_deadlock_would_occur**: if deadlock is detected or this->get_id() == boost::this_thread::get_id().

**invalid_argument**: if the thread is not joinable and BOOST_THREAD_TRHOW_IF_PRECONDITION_NOT_SATISFIED is defined.

Notes: `try_join_until()` is one of the predefined *interruption points*.

## Member function `detach()`

```
void detach();
```

Preconditions: the thread is joinable.

Effects: The thread of execution becomes detached, and no longer has an associated `boost::thread` object.

Postconditions: `*this` no longer refers to any thread of execution.

Throws: `system_error`

Error Conditions: **no_such_process**: if the thread is not valid.

**invalid_argument**: if the thread is not joinable and BOOST_THREAD_TRHOW_IF_PRECONDITION_NOT_SATISFIED is defined.

## Member function `get_id()`

```
thread::id get_id() const noexcept;
```

Returns: If `*this` refers to a thread of execution, an instance of `boost::thread::id` that represents that thread. Otherwise returns a default-constructed `boost::thread::id`.

Throws: Nothing

## Member function `interrupt()` EXTENSION

```
void interrupt();
```

Effects: If `*this` refers to a thread of execution, request that the thread will be interrupted the next time it enters one of the predefined *interruption points* with interruption enabled, or if it is currently *blocked* in a call to one of the predefined *interruption points* with interruption enabled .

Throws: Nothing

## Static member function `hardware_concurrency()`

```
unsigned hardware_concurrency() noexecpt;
```

Returns: The number of hardware threads available on the current system (e.g. number of CPUs or cores or hyperthreading units), or 0 if this information is not available.

Throws: Nothing

## Member function `native_handle()`

```
typedef platform-specific-type native_handle_type;
native_handle_type native_handle();
```

Effects: Returns an instance of `native_handle_type` that can be used with platform-specific APIs to manipulate the underlying implementation. If no such instance exists, `native_handle()` and `native_handle_type` are not present.

Throws: Nothing.

## `operator==` DEPRECATED

```
bool operator==(const thread& other) const;
```

### Warning

DEPRECATED since 4.0.0.

Available only up to Boost 1.58.

Use `a.get_id()==b.get_id()` instead`.

Returns: `get_id()==other.get_id()`

## `operator!=` DEPRECATED

```
bool operator!=(const thread& other) const;
```

> **Warning**
>
> DEPRECATED since 4.0.0.
>
> Available only up to Boost 1.58.
>
> Use `a.get_id()!=b.get_id()` instead`.

Returns: `get_id()!=other.get_id()`

## Static member function `sleep()` DEPRECATED

```
void sleep(system_time const& abs_time);
```

> **Warning**
>
> DEPRECATED since 3.0.0.
>
> Available only up to Boost 1.56.
>
> Use `this_thread::sleep_for()` or `this_thread::sleep_until()`.

Effects: Suspends the current thread until the specified time has been reached.

Throws: `boost::thread_interrupted` if the current thread of execution is interrupted.

Notes: `sleep()` is one of the predefined *interruption points*.

## Static member function `yield()` DEPRECATED

```
void yield();
```

> **Warning**
>
> DEPRECATED since 3.0.0.
>
> Available only up to Boost 1.56.
>
> Use `this_thread::yield()`.

Effects: See `boost::this_thread::yield()`.

## Member function `swap()`

```
void swap(thread& other) noexcept;
```

Effects: Exchanges the threads of execution associated with `*this` and `other`, so `*this` is associated with the thread of execution associated with `other` prior to the call, and vice-versa.

Postconditions: `this->get_id()` returns the same value as `other.get_id()` prior to the call. `other.get_id()` returns the same value as `this->get_id()` prior to the call.

Throws: Nothing.

## Non-member function `swap()`

```
#include <boost/thread/thread.hpp>

void swap(thread& lhs,thread& rhs) noexcept;
```

Effects: `lhs.swap(rhs)`.

## Class `boost::thread::id`

```
#include <boost/thread/thread.hpp>

class thread::id
{
public:
    id() noexcept;

    bool operator==(const id& y) const noexcept;
    bool operator!=(const id& y) const noexcept;
    bool operator<(const id& y) const noexcept;
    bool operator>(const id& y) const noexcept;
    bool operator<=(const id& y) const noexcept;
    bool operator>=(const id& y) const noexcept;

    template<class charT, class traits>
    friend std::basic_ostream<charT, traits>&
    operator<<(std::basic_ostream<charT, traits>& os, const id& x);
};
```

### Default constructor

```
id() noexcept;
```

Effects: Constructs a `boost::thread::id` instance that represents *Not-a-Thread*.

Throws: Nothing

#### `operator==`

```
bool operator==(const id& y) const noexcept;
```

Returns: `true` if `*this` and `y` both represent the same thread of execution, or both represent *Not-a-Thread*, `false` otherwise.

Throws: Nothing

#### `operator!=`

```
bool operator!=(const id& y) const noexcept;
```

Returns: `true` if `*this` and `y` represent different threads of execution, or one represents a thread of execution, and the other represent *Not-a-Thread*, `false` otherwise.

Throws: Nothing

### `operator<`

```
bool operator<(const id& y) const noexcept;
```

Returns: `true` if `*this!=y` is `true` and the implementation-defined total order of `boost::thread::id` values places `*this` before `y`, `false` otherwise.

Throws: Nothing

Note: A `boost::thread::id` instance representing *Not-a-Thread* will always compare less than an instance representing a thread of execution.

### `operator>`

```
bool operator>(const id& y) const noexcept;
```

Returns: `y<*this`

Throws: Nothing

### `operator<=`

```
bool operator<=(const id& y) const noexcept;
```

Returns: `!(y<*this)`

Throws: Nothing

### `operator>=`

```
bool operator>=(const id& y) const noexcept;
```

Returns: `!(*this<y)`

Throws: Nothing

## Friend `operator<<`

```
template<class charT, class traits>
friend std::basic_ostream<charT, traits>&
operator<<(std::basic_ostream<charT, traits>& os, const id& x);
```

Effects: Writes a representation of the `boost::thread::id` instance `x` to the stream `os`, such that the representation of two instances of `boost::thread::id` `a` and `b` is the same if `a==b`, and different if `a!=b`.

Returns: `os`

# Class `boost::thread::attributes` EXTENSION

```
class thread::attributes {
public:
    attributes() noexcept;
    ~ attributes()=default;
    // stack
    void set_stack_size(std::size_t size) noexcept;
    std::size_t get_stack_size() const noexcept;

#if defined BOOST_THREAD_DEFINES_THREAD_ATTRIBUTES_NATIVE_HANDLE
    typedef platform-specific-type native_handle_type;
    native_handle_type* native_handle() noexcept;
    const native_handle_type* native_handle() const noexcept;
#endif

};
```

## Default constructor

```
thread_attributes() noexcept;
```

Effects: Constructs a thread atrributes instance with its default values.

Throws: Nothing

## Member function `set_stack_size()`

```
void set_stack_size(std::size_t size) noexcept;
```

Effects: Stores the stack size to be used to create a thread. This is an hint that the implementation can choose a better size if to small or too big or not aligned to a page.

Postconditions: `this-> get_stack_size()` returns the chosen stack size.

Throws: Nothing.

## Member function `get_stack_size()`

```
std::size_t get_stack_size() const noexcept;
```

Returns: The stack size to be used on the creation of a thread. Note that this function can return 0 meaning the default.

Throws: Nothing.

## Member function `native_handle()`

```
typedef platform-specific-type native_handle_type;
    typedef platform-specific-type native_handle_type;
    native_handle_type* native_handle() noexcept;
    const native_handle_type* native_handle() const noexcept;
```

Effects: Returns an instance of `native_handle_type` that can be used with platform-specific APIs to manipulate the underlying thread attributes implementation. If no such instance exists, `native_handle()` and `native_handle_type` are not present and `BOOST_THREAD_DEFINES_THREAD_ATTRIBUTES_NATIVE_HANDLE` is not defined.

Throws: Nothing.

## Namespace `this_thread`

```
namespace boost {
  namespace this_thread {
    thread::id get_id() noexcept;
    template<typename TimeDuration>
    void yield() noexcept;
    template <class Clock, class Duration>
    void sleep_until(const chrono::time_point<Clock, Duration>& abs_time);
    template <class Rep, class Period>
    void sleep_for(const chrono::duration<Rep, Period>& rel_time);

    template<typename Callable>
    void at_thread_exit(Callable func); // EXTENSION

    void interruption_point(); // EXTENSION
    bool interruption_requested() noexcept; // EXTENSION
    bool interruption_enabled() noexcept; // EXTENSION
    class disable_interruption; // EXTENSION
    class restore_interruption; // EXTENSION

  #if defined BOOST_THREAD_USES_DATETIME
    void sleep(TimeDuration const& rel_time); // DEPRECATED
    void sleep(system_time const& abs_time);  // DEPRECATED
  #endif
  }
}
```

### Non-member function `get_id()`

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
    thread::id get_id() noexcept;
}
```

Returns: An instance of `boost::thread::id` that represents that currently executing thread.

Throws: `boost::thread_resource_error` if an error occurs.

### Non-member function `interruption_point()` EXTENSION

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
    void interruption_point();
}
```

Effects: Check to see if the current thread has been interrupted.

Throws: `boost::thread_interrupted` if `boost::this_thread::interruption_enabled()` and `boost::this_thread::interruption_requested()` both return `true`.

## Non-member function `interruption_requested()` EXTENSION

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
    bool interruption_requested() noexcept;
}
```

Returns: `true` if interruption has been requested for the current thread, `false` otherwise.

Throws: Nothing.

## Non-member function `interruption_enabled()` EXTENSION

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
    bool interruption_enabled() noexcept;
}
```

Returns: `true` if interruption has been enabled for the current thread, `false` otherwise.

Throws: Nothing.

## Non-member function `sleep()` DEPRECATED

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
    template<typename TimeDuration>
    void sleep(TimeDuration const& rel_time);
    void sleep(system_time const& abs_time)
}
```

**Warning**

DEPRECATED since 3.0.0.

Available only up to Boost 1.56.

Use `sleep_for()` and `sleep_until()` instead.

Effects: Suspends the current thread until the time period specified by `rel_time` has elapsed or the time point specified by `abs_time` has been reached.

Throws: `boost::thread_interrupted` if the current thread of execution is interrupted.

Notes: `sleep()` is one of the predefined *interruption points*.

## Non-member function `sleep_until()`

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
  template <class Clock, class Duration>
  void sleep_until(const chrono::time_point<Clock, Duration>& abs_time);
}
```

Effects: Suspends the current thread until the time point specified by `abs_time` has been reached.

Throws: Nothing if Clock satisfies the TrivialClock requirements and operations of Duration do not throw exceptions. `boost::thread_interrupted` if the current thread of execution is interrupted.

Notes: `sleep_until()` is one of the predefined *interruption points*.

## Non-member function `sleep_for()`

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
  template <class Rep, class Period>
  void sleep_for(const chrono::duration<Rep, Period>& rel_time);
}
```

Effects: Suspends the current thread until the duration specified by by `rel_time` has elapsed.

Throws: Nothing if operations of chrono::duration<Rep, Period> do not throw exceptions. `boost::thread_interrupted` if the current thread of execution is interrupted.

Notes: `sleep_for()` is one of the predefined *interruption points*.

## Non-member function `yield()`

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
    void yield() noexcept;
}
```

Effects: Gives up the remainder of the current thread's time slice, to allow other threads to run.

Throws: Nothing.

## Class `disable_interruption` EXTENSION

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
    class disable_interruption
    {
    public:
        disable_interruption(const disable_interruption&) = delete;
        disable_interruption& operator=(const disable_interruption&) = delete;
        disable_interruption() noexcept;
        ~disable_interruption() noexcept;
    };
}
```

`boost::this_thread::disable_interruption` disables interruption for the current thread on construction, and restores the prior interruption state on destruction. Instances of `disable_interruption` cannot be copied or moved.

### Constructor

```
disable_interruption() noexcept;
```

| | |
|---|---|
| Effects: | Stores the current state of `boost::this_thread::interruption_enabled()` and disables interruption for the current thread. |
| Postconditions: | `boost::this_thread::interruption_enabled()` returns `false` for the current thread. |
| Throws: | Nothing. |

### Destructor

```
~disable_interruption() noexcept;
```

| | |
|---|---|
| Preconditions: | Must be called from the same thread from which `*this` was constructed. |
| Effects: | Restores the current state of `boost::this_thread::interruption_enabled()` for the current thread to that prior to the construction of `*this`. |
| Postconditions: | `boost::this_thread::interruption_enabled()` for the current thread returns the value stored in the constructor of `*this`. |
| Throws: | Nothing. |

## Class `restore_interruption` EXTENSION

```
#include <boost/thread/thread.hpp>

namespace this_thread
{
    class restore_interruption
    {
    public:
        restore_interruption(const restore_interruption&) = delete;
        restore_interruption& operator=(const restore_interruption&) = delete;
        explicit restore_interruption(disable_interruption& disabler) noexcept;
        ~restore_interruption() noexcept;
    };
}
```

On construction of an instance of `boost::this_thread::restore_interruption`, the interruption state for the current thread is restored to the interruption state stored by the constructor of the supplied instance of `boost::this_thread::disable_interruption`. When the instance is destroyed, interruption is again disabled. Instances of `restore_interruption` cannot be copied or moved.

### Constructor

```
explicit restore_interruption(disable_interruption& disabler) noexcept;
```

Preconditions: Must be called from the same thread from which `disabler` was constructed.

Effects: Restores the current state of `boost::this_thread::interruption_enabled()` for the current thread to that prior to the construction of `disabler`.

Postconditions: `boost::this_thread::interruption_enabled()` for the current thread returns the value stored in the constructor of `disabler`.

Throws: Nothing.

### Destructor

```
~restore_interruption() noexcept;
```

Preconditions: Must be called from the same thread from which `*this` was constructed.

Effects: Disables interruption for the current thread.

Postconditions: `boost::this_thread::interruption_enabled()` for the current thread returns `false`.

Throws: Nothing.

## Non-member function template `at_thread_exit()` EXTENSION

```
#include <boost/thread/thread.hpp>

template<typename Callable>
void at_thread_exit(Callable func);
```

Effects: A copy of `func` is placed in thread-specific storage. This copy is invoked when the current thread exits (even if the thread has been interrupted).

Postconditions: A copy of `func` has been saved for invocation on thread exit.

Throws: `std::bad_alloc` if memory cannot be allocated for the copy of the function, `boost::thread_resource_error` if any other error occurs within the thread library. Any exception thrown whilst copying `func` into internal storage.

Note: This function is **not** called if the thread was terminated forcefully using platform-specific APIs, or if the thread is terminated due to a call to `exit()`, `abort()` or `std::terminate()`. In particular, returning from `main()` is equivalent to call to `exit()`, so will not call any functions registered with `at_thread_exit()`

# Class `thread_group` EXTENSION

```
#include <boost/thread/thread.hpp>
#include <boost/thread/thread_group.hpp>

class thread_group
{
public:
    thread_group(const thread_group&) = delete;
    thread_group& operator=(const thread_group&) = delete;

    thread_group();
    ~thread_group();

    template<typename F>
    thread* create_thread(F threadfunc);
    void add_thread(thread* thrd);
    void remove_thread(thread* thrd);
    bool is_this_thread_in();
    bool is_thread_in(thread* thrd);
    void join_all();
    void interrupt_all();
    int size() const;
};
```

`thread_group` provides for a collection of threads that are related in some fashion. New threads can be added to the group with `add_thread` and `create_thread` member functions. `thread_group` is not copyable or movable.

## Constructor

```
thread_group();
```

Effects: Create a new thread group with no threads.

## Destructor

```
~thread_group();
```

Effects: Destroy `*this` and `delete` all `boost::thread` objects in the group.

## Member function `create_thread()`

```
template<typename F>
thread* create_thread(F threadfunc);
```

Effects: Create a new `boost::thread` object as-if by `new thread(threadfunc)` and add it to the group.

Postcondition: `this->size()` is increased by one, the new thread is running.

Returns: A pointer to the new `boost::thread` object.

## Member function `add_thread()`

```
void add_thread(thread* thrd);
```

Precondition: The expression `delete thrd` is well-formed and will not result in undefined behaviour and `is_thread_in(thrd) == false`.

Effects: Take ownership of the `boost::thread` object pointed to by `thrd` and add it to the group.

Postcondition: `this->size()` is increased by one.

## Member function `remove_thread()`

```
void remove_thread(thread* thrd);
```

Effects: If `thrd` is a member of the group, remove it without calling `delete`.

Postcondition: If `thrd` was a member of the group, `this->size()` is decreased by one.

## Member function `join_all()`

```
void join_all();
```

Requires: `is_this_thread_in() == false`.

Effects: Call `join()` on each `boost::thread` object in the group.

Postcondition: Every thread in the group has terminated.

Note: Since `join()` is one of the predefined *interruption points*, `join_all()` is also an interruption point.

## Member function `is_this_thread_in()`

```
bool is_this_thread_in();
```

Returns: true if there is a thread `th` in the group such that `th.get_id() == this_thread::get_id()`.

## Member function `is_thread_in()`

```
bool is_thread_in(thread* thrd);
```

Returns: true if there is a thread `th` in the group such that `th.get_id() == thrd->get_id()`.

## Member function `interrupt_all()`

```
void interrupt_all();
```

Effects: Call `interrupt()` on each `boost::thread` object in the group.

## Member function `size()`

```
int size();
```

Returns: The number of threads in the group.

Throws: Nothing.

# Scoped Threads

## Synopsis

```
//#include <boost/thread/scoped_thread.hpp>

struct detach;
struct join_if_joinable;
struct interrupt_and_join_if_joinable;
template <class CallableThread = join_if_joinable>
class strict_scoped_thread;
template <class CallableThread = join_if_joinable>
class scoped_thread;
void swap(scoped_thread& lhs,scoped_thread& rhs) noexcept;
```

# Motivation

Based on the scoped_thread class defined in C++ Concurrency in Action Boost.Thread defines a thread wrapper class that instead of calling terminate if the thread is joinable on destruction, call a specific action given as template parameter.

While the scoped_thread class defined in C++ Concurrency in Action is closer to strict_scoped_thread class that doesn't allows any change in the wrapped thread, Boost.Thread provides a class scoped_thread that provides the same non-deprecated interface than `thread`.

# Tutorial

Scoped Threads are wrappers around a thread that allows the user to state what to do at destruction time. One of the common uses is to join the thread at destruction time so this is the default behavior. This is the single difference respect to a thread. While thread call std::terminate() on the destructor is the thread is joinable, strict_scoped_thread<> or scoped_thread<> join the thread if joinable.

The difference between strict_scoped_thread and scoped_thread is that the strict_scoped_thread hides completely the owned thread and so the user can do nothing with the owned thread other than the specific action given as parameter, while scoped_thread provide the same interface than `thread` and forwards all the operations.

```
boost::strict_scoped_thread<> t1((boost::thread(F)));
boost::strict_scoped_thread<> t2((boost::thread(F)));
t2.interrupt();
```

# Free Thread Functors

```
//#include <boost/thread/scoped_thread.hpp>

struct detach;
struct join_if_joinable;
struct interrupt_and_join_if_joinable;
```

## Functor `detach`

```
struct detach
{
  void operator()(thread& t)
  {
    t.detach();
  }
};
```

## Functor `join_if_joinable`

```
struct join_if_joinable
{
  void operator()(thread& t)
  {
    if (t.joinable())
    {
      t.join();
    }
  }
};
```

## Functor `interrupt_and_join_if_joinable`

```
struct interrupt_and_join_if_joinable
{
  void operator()(thread& t)
  {
    t.interrupt();
    if (t.joinable())
    {
      t.join();
    }
  }
};
```

## Class `strict_scoped_thread`

```
// #include <boost/thread/scoped_thread.hpp>

template <class CallableThread = join_if_joinable>
class strict_scoped_thread
{
  thread t_; // for exposition purposes only
public:

  strict_scoped_thread(strict_scoped_thread const&) = delete;
  strict_scoped_thread& operator=(strict_scoped_thread const&) = delete;

  explicit strict_scoped_thread(thread&& t) noexcept;

  ~strict_scoped_thread();

};
```

RAI `thread` wrapper adding a specific destroyer allowing to master what can be done at destruction time.

CallableThread: A callable `void(thread&)`.

The default is a `join_if_joinable`.

`std/boost::thread` destructor terminates the program if the `thread` is not joinable. This wrapper can be used to join the thread before destroying it seems a natural need.

### Example

```
boost::strict_scoped_thread<> t((boost::thread(F)));
```

## Default Constructor

```
explicit strict_scoped_thread(thread&& t) noexcept;
```

Effects: move the thread to own `t_`

Throws: Nothing

## Destructor

```
~strict_scoped_thread();
```

Effects: Equivalent to `CallableThread()(t_)`.

Throws: Nothing: The `CallableThread()(t_)` should not throw when joining the thread as the scoped variable is on a scope outside the thread function.

# Class `scoped_thread`

```
#include <boost/thread/scoped_thread.hpp>

class scoped_thread
{
  thread t_; // for exposition purposes only
public:
    scoped_thread() noexcept;
    scoped_thread(const scoped_thread&) = delete;
    scoped_thread& operator=(const scoped_thread&) = delete;

    explicit scoped_thread(thread&& th) noexcept;

    ~scoped_thread();

    // move support
    scoped_thread(scoped_thread && x) noexcept;
    scoped_thread& operator=(scoped_thread && x) noexcept;

    void swap(scoped_thread& x) noexcept;

    typedef thread::id id;

    id get_id() const noexcept;

    bool joinable() const noexcept;
    void join();
#ifdef BOOST_THREAD_USES_CHRONO
    template <class Rep, class Period>
    bool try_join_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_join_until(const chrono::time_point<Clock, Duration>& t);
#endif

    void detach();

    static unsigned hardware_concurrency() noexcept;

    typedef thread::native_handle_type native_handle_type;
    native_handle_type native_handle();

#if defined BOOST_THREAD_PROVIDES_INTERRUPTIONS
    void interrupt();
    bool interruption_requested() const noexcept;
#endif


};

void swap(scoped_thread& lhs,scoped_thread& rhs) noexcept;
```

RAI `thread` wrapper adding a specific destroyer allowing to master what can be done at destruction time.

CallableThread: A callable void(thread&). The default is join_if_joinable.

thread std::thread destructor terminates the program if the thread is not joinable. Having a wrapper that can join the thread before destroying it seems a natural need.

Remark: `scoped_thread` is not a `thread` as `thread` is not designed to be derived from as a polymorphic type.

Anyway `scoped_thread` can be used in most of the contexts a `thread` could be used as it has the same non-deprecated interface with the exception of the construction.

### Example

```
boost::scoped_thread<> t((boost::thread(F)));
t.interrupt();
```

## Default Constructor

```
scoped_thread() noexcept;
```

Effects: Constructs a scoped_thread instance that wraps to *Not-a-Thread*.

Postconditions: `this->get_id()==thread::id()`

Throws: Nothing

## Move Constructor

```
scoped_thread(scoped_thread&& other) noexcept;
```

Effects: Transfers ownership of the scoped_thread managed by `other` (if any) to the newly constructed scoped_thread instance.

Postconditions: `other.get_id()==thread::id()` and `get_id()` returns the value of `other.get_id()` prior to the construction

Throws: Nothing

## Move assignment operator

```
scoped_thread& operator=(scoped_thread&& other) noexcept;
```

Effects: Transfers ownership of the scoped_thread managed by `other` (if any) to `*this`.

- if defined `BOOST_THREAD_DONT_PROVIDE_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE`: If there was a `scoped_thread` previously associated with `*this` then that `scoped_thread` is detached, DEPRECATED

- if defined `BOOST_THREAD_PROVIDES_THREAD_MOVE_ASSIGN_CALLS_TERMINATE_IF_JOINABLE`: If the `scoped_thread` is joinable calls to std::terminate.

Postconditions: `other->get_id()==thread::id()` and `get_id()` returns the value of `other.get_id()` prior to the assignment.

Throws: Nothing

## Move Constructor from a `thread`

```
scoped_thread(thread&& t);
```

Effects: move the thread to own `t_`.

Postconditions: `*this.t_` refers to the newly created thread of execution and `this->get_id()!=thread::id()`.

Throws: Nothing

## Destructor

```
~scoped_thread();
```

Effects: Equivalent to `CallableThread()(t_)`.

Throws: Nothing: The `CallableThread()(t_)` should not throw when joining the thread as the scoped variable is on a scope outside the thread function.

## Member function `joinable()`

```
bool joinable() const noexcept;
```

Returns: Equivalent to return t_.joinable().

Throws: Nothing

## Member function `join()`

```
void join();
```

Effects: Equivalent to t_.join().

## Member function `try_join_for()`

```
template <class Rep, class Period>
bool try_join_for(const chrono::duration<Rep, Period>& rel_time);
```

Effects: Equivalent to return `t_.try_join_for(rel_time)`.

## Member function `try_join_until()`

```
template <class Clock, class Duration>
bool try_join_until(const chrono::time_point<Clock, Duration>& abs_time);
```

Effects: Equivalent to return `t_.try_join_until(abs_time)`.

## Member function `detach()`

```
void detach();
```

Effects: Equivalent to `t_.detach()`.

## Member function `get_id()`

```
thread::id get_id() const noexcept;
```

Effects: Equivalent to return `t_.get_id()`.

## Member function `interrupt()`

```
void interrupt();
```

Effects: Equivalent to `t_.interrupt()`.

## Static member function `hardware_concurrency()`

```
unsigned hardware_concurrency() noexecpt;
```

Effects: Equivalent to return `thread::hardware_concurrency()`.

## Member function `native_handle()`

```
typedef thread::native_handle_type native_handle_type;
native_handle_type native_handle();
```

Effects: Equivalent to return `t_.native_handle()`.

## Member function `swap()`

```
void swap(scoped_thread& other) noexcept;
```

Effects: Equivalent `t_.swap(other.t_)`.

# Non-member function `swap(scoped_thread&,scoped_thread&)`

```
#include <boost/thread/scoped_thread.hpp>

void swap(scoped_thread& lhs,scoped_thread& rhs) noexcept;
```

Effects: `lhs.swap(rhs)`.

# Synchronization

## Tutorial

Handling mutexes in C++ is an excellent tutorial. You need just replace std and ting by boost.

Mutex, Lock, Condition Variable Rationale adds rationale for the design decisions made for mutexes, locks and condition variables.

In addition to the C++11 standard locks, Boost.Thread provides other locks and some utilities that help the user to make their code thread-safe.

## Internal Locking

**Note**

This tutorial is an adaptation of chapter Concurrency of the Object-Oriented Programming in the BETA Programming Language and of the paper of Andrei Alexandrescu "Multithreading and the C++ Type System" to the Boost library.

### Concurrent threads of execution

Consider, for example, modeling a bank account class that supports simultaneous deposits and withdrawals from multiple locations (arguably the "Hello, World" of multithreaded programming).

From here a component is a model of the `Callable` concept.

On C++11 (Boost) concurrent execution of a component is obtained by means of the `std::thread`(`boost::thread`):

```
boost::thread thread1(S);
```

where `S` is a model of `Callable`. The meaning of this expression is that execution of `S()` will take place concurrently with the current thread of execution executing the expression.

The following example includes a bank account of a person (Joe) and two components, one corresponding to a bank agent depositing money in Joe's account, and one representing Joe. Joe will only be withdrawing money from the account:

```
class BankAccount;

BankAccount JoesAccount;

void bankAgent()
{
    for (int i =10; i>0; --i) {
        //...
        JoesAccount.Deposit(500);
        //...
    }
}

void Joe() {
    for (int i =10; i>0; --i) {
        //...
        int myPocket = JoesAccount.Withdraw(100);
        std::cout << myPocket << std::endl;
        //...
    }
}

int main() {
    //...
    boost::thread thread1(bankAgent); // start concurrent execution of bankAgent
    boost::thread thread2(Joe); // start concurrent execution of Joe
    thread1.join();
    thread2.join();
    return 0;
}
```

From time to time, the `bankAgent` will deposit $500 in `JoesAccount`. Joe will similarly withdraw $100 from his account. These sentences describe that the bankAgent and Joe are executed concurrently.

The above example works well as long as the bankAgent and Joe doesn't access JoesAccount at the same time. There is, however, no guarantee that this will not happen. We may use a mutex to guarantee exclusive access to each bank.

```
class BankAccount {
    boost::mutex mtx_;
    int balance_;
public:
    void Deposit(int amount) {
        mtx_.lock();
        balance_ += amount;
        mtx_.unlock();
    }
    void Withdraw(int amount) {
        mtx_.lock();
        balance_ -= amount;
        mtx_.unlock();
    }
    int GetBalance() {
        mtx_.lock();
        int b = balance_;
        mtx_.unlock();
        return balance_;
    }
};
```

Execution of the Deposit and Withdraw operations will no longer be able to make simultaneous access to balance.

Mutex is a simple and basic mechanism for obtaining synchronization. In the above example it is relatively easy to be convinced that the synchronization works correctly (in the absence of exception). In a system with several concurrent objects and several shared objects, it may be difficult to describe synchronization by means of mutexes. Programs that make heavy use of mutexes may be difficult to read and write. Instead, we shall introduce a number of generic classes for handling more complicated forms of synchronization and communication.

With the RAII idiom we can simplify a lot this using the scoped locks. In the code below, guard's constructor locks the passed-in object this, and guard's destructor unlocks this.

```
class BankAccount {
    boost::mutex mtx_; // explicit mutex declaration
    int balance_;
public:
    void Deposit(int amount) {
        boost::lock_guard<boost::mutex> guard(mtx_);
        balance_ += amount;
    }
    void Withdraw(int amount) {
        boost::lock_guard<boost::mutex> guard(mtx_);
        balance_ -= amount;
    }
    int GetBalance() {
        boost::lock_guard<boost::mutex> guard(mtx_);
        return balance_;
    }
};
```

The object-level locking idiom doesn't cover the entire richness of a threading model. For example, the model above is quite deadlock-prone when you try to coordinate multi-object transactions. Nonetheless, object-level locking is useful in many cases, and in combination with other mechanisms can provide a satisfactory solution to many threaded access problems in object-oriented programs.

The BankAccount class above uses internal locking. Basically, a class that uses internal locking guarantees that any concurrent calls to its public member functions don't corrupt an instance of that class. This is typically ensured by having each public member function acquire a lock on the object upon entry. This way, for any given object of that class, there can be only one member function call active at any moment, so the operations are nicely serialized.

This approach is reasonably easy to implement and has an attractive simplicity. Unfortunately, "simple" might sometimes morph into "simplistic."

Internal locking is insufficient for many real-world synchronization tasks. Imagine that you want to implement an ATM withdrawal transaction with the BankAccount class. The requirements are simple. The ATM transaction consists of two withdrawals-one for the actual money and one for the $2 commission. The two withdrawals must appear in strict sequence; that is, no other transaction can exist between them.

The obvious implementation is erratic:

```
void ATMWithdrawal(BankAccount& acct, int sum) {
    acct.Withdraw(sum);
    // preemption possible
    acct.Withdraw(2);
}
```

The problem is that between the two calls above, another thread can perform another operation on the account, thus breaking the second design requirement.

In an attempt to solve this problem, let's lock the account from the outside during the two operations:

```
void ATMWithdrawal(BankAccount& acct, int sum) {
    boost::lock_guard<boost::mutex> guard(acct.mtx_); 1
    acct.Withdraw(sum);
    acct.Withdraw(2);
}
```

Notice that the code above doesn't compiles, the `mtx_` field is private. We have two possibilities:

- make `mtx_` public which seams odd
- make the `BankAccount` lockable by adding the lock/unlock functions

We can add these functions explicitly

```
class BankAccount {
    boost::mutex mtx_;
    int balance_;
public:
    void Deposit(int amount) {
        boost::lock_guard<boost::mutex> guard(mtx_);
        balance_ += amount;
    }
    void Withdraw(int amount) {
        boost::lock_guard<boost::mutex> guard(mtx_);
        balance_ -= amount;
    }
    void lock() {
        mtx_.lock();
    }
    void unlock() {
        mtx_.unlock();
    }
};
```

or inheriting from a class which add these lockable functions.

The `basic_lockable_adapter` class helps to define the `BankAccount` class as

```
class BankAccount
: public basic_lockable_adapter<mutex>
{
    int balance_;
public:
    void Deposit(int amount) {
        boost::lock_guard<BankAccount> guard(*this);
        balance_ += amount;
    }
    void Withdraw(int amount) {
        boost::lock_guard<BankAccount> guard(*this);
        balance_ -= amount;
    }
    int GetBalance() {
        boost::lock_guard<BankAccount> guard(*this);
        return balance_;
    }
};
```

and the code that doesn't compiles becomes

```
void ATMWithdrawal(BankAccount& acct, int sum) {
    boost::lock_guard<BankAccount> guard(acct);
    acct.Withdraw(sum);
    acct.Withdraw(2);
}
```

Notice that now acct is being locked by Withdraw after it has already been locked by guard. When running such code, one of two things happens.

- Your mutex implementation might support the so-called recursive mutex semantics. This means that the same thread can lock the same mutex several times successfully. In this case, the implementation works but has a performance overhead due to unnecessary locking. (The locking/unlocking sequence in the two Withdraw calls is not needed but performed anyway-and that costs time.)
- Your mutex implementation might not support recursive locking, which means that as soon as you try to acquire it the second time, it blocks-so the ATMWithdrawal function enters the dreaded deadlock.

As boost::mutex is not recursive, we need to use its recursive version boost::recursive_mutex.

```
class BankAccount
: public basic_lockable_adapter<recursive_mutex>
{

    // ...
};
```

### Synchronized variables

## External Locking -- strict_lock and externally_locked classes

> **Note**
>
> This tutorial is an adaptation of the paper of Andrei Alexandrescu "Multithreading and the C++ Type System" to the Boost library.

### Locks as Permits

So what to do? Ideally, the BankAccount class should do the following:

- Support both locking models (internal and external).
- Be efficient; that is, use no unnecessary locking.
- Be safe; that is, BankAccount objects cannot be manipulated without appropriate locking.

Let's make a worthwhile observation: Whenever you lock a BankAccount, you do so by using a lock_guard<BankAccount> object. Turning this statement around, wherever there's a lock_guard<BankAccount>, there's also a locked BankAccount somewhere. Thus, you can think of-and use-a lock_guard<BankAccount> object as a permit. Owning a lock_guard<BankAccount> gives you rights to do certain things. The lock_guard<BankAccount> object should not be copied or aliased (it's not a transmissible permit).

1. As long as a permit is still alive, the BankAccount object stays locked.
2. When the lock_guard<BankAccount> is destroyed, the BankAccount's mutex is released.

The net effect is that at any point in your code, having access to a lock_guard<BankAccount> object guarantees that a BankAccount is locked. (You don't know exactly which BankAccount is locked, however-an issue that we'll address soon.)

For now, let's make a couple of enhancements to the `lock_guard` class template defined in Boost.Thread. We'll call the enhanced version `strict_lock`. Essentially, a `strict_lock`'s role is only to live on the stack as an automatic variable. `strict_lock` must adhere to a non-copy and non-alias policy. `strict_lock` disables copying by making the copy constructor and the assignment operator private. While we're at it, let's disable operator new and operator delete; `strict_lock` are not intended to be allocated on the heap. `strict_lock` avoids aliasing by using a slightly less orthodox and less well-known technique: disable address taking.

```
template <typename Lockable>
class strict_lock  {
public:
    typedef Lockable lockable_type;


    explicit strict_lock(lockable_type& obj) : obj_(obj) {
        obj.lock(); // locks on construction
    }
    strict_lock() = delete;
    strict_lock(strict_lock const&) = delete;
    strict_lock& operator=(strict_lock const&) = delete;

    ~strict_lock() { obj_.unlock(); } //  unlocks on destruction

    bool owns_lock(mutex_type const* l) const noexcept // strict lockers specific function
    {
      return l == &obj_;
    }
private:
    lockable_type& obj_;
};
```

Silence can be sometimes louder than words-what's forbidden to do with a `strict_lock` is as important as what you can do. Let's see what you can and what you cannot do with a `strict_lock` instantiation:

- You can create a `strict_lock<T>` only starting from a valid T object. Notice that there is no other way you can create a `strict_lock<T>`.

```
BankAccount myAccount("John Doe", "123-45-6789");
strict_locerk<BankAccount> myLock(myAccount); // ok
```

- You cannot copy `strict_lock`s to one another. In particular, you cannot pass `strict_lock`s by value to functions or have them returned by functions:

```
extern strict_lock<BankAccount> Foo(); // compile-time error
extern void Bar(strict_lock<BankAccount>); // compile-time error
```

- However, you still can pass `strict_lock`s by reference to and from functions:

```
// ok, Foo returns a reference to strict_lock<BankAccount>
extern strict_lock<BankAccount>& Foo();
// ok, Bar takes a reference to strict_lock<BankAccount>
extern void Bar(strict_lock<BankAccount>&);
```

- You cannot allocate a `strict_lock` on the heap. However, you still can put `strict_lock`s on the heap if they're members of a class.

```
strict_lock<BankAccount>* pL =
    new strict_lock<BankAccount>(myAcount); //error!
    // operator new is not accessible
class Wrapper {
    strict_lock memberLock_;
    ...
};
Wrapper* pW = new Wrapper; // ok
```

(Making `strict_lock` a member variable of a class is not recommended. Fortunately, disabling copying and default construction makes `strict_lock` quite an unfriendly member variable.)

- You cannot take the address of a `strict_lock` object. This interesting feature, implemented by disabling unary operator&, makes it very unlikely to alias a `strict_lock` object. Aliasing is still possible by taking references to a `strict_lock`:

```
strict_lock<BankAccount> myLock(myAccount); // ok
strict_lock<BankAccount>* pAlias = &myLock; // error!
    // strict_lock<BankAccount>::operator& is not accessible
strict_lock<BankAccount>& rAlias = myLock; // ok
```

Fortunately, references don't engender as bad aliasing as pointers because they're much less versatile (references cannot be copied or reseated).

- You can even make `strict_lock` final; that is, impossible to derive from. This task is left in the form of an exercise to the reader.

All these rules were put in place with one purpose-enforcing that owning a `strict_lock<T>` is a reasonably strong guarantee that

1. you locked a T object, and
2. that object will be unlocked at a later point.

Now that we have such a strict `strict_lock`, how do we harness its power in defining a safe, flexible interface for BankAccount? The idea is as follows:

- Each of BankAccount's interface functions (in our case, Deposit and Withdraw) comes in two overloaded variants.
- One version keeps the same signature as before, and the other takes an additional argument of type `strict_lock<BankAccount>`. The first version is internally locked; the second one requires external locking. External locking is enforced at compile time by requiring client code to create a `strict_lock<BankAccount>` object.
- BankAccount avoids code bloating by having the internal locked functions forward to the external locked functions, which do the actual job.

A little code is worth 1,000 words, a (hacked into) saying goes, so here's the new BankAccount class:

```
class BankAccount
: public basic_lockable_adapter<boost:recursive_mutex>
{
    int balance_;
public:
    void Deposit(int amount, strict_lock<BankAccount>&) {
        // Externally locked
        balance_ += amount;
    }
    void Deposit(int amount) {
        strict_lock<boost:mutex> guard(*this); // Internally locked
        Deposit(amount, guard);
    }
    void Withdraw(int amount, strict_lock<BankAccount>&) {
        // Externally locked
        balance_ -= amount;
    }
    void Withdraw(int amount) {
        strict_lock<boost:mutex> guard(*this); // Internally locked
        Withdraw(amount, guard);
    }
};
```

Now, if you want the benefit of internal locking, you simply call Deposit(int) and Withdraw(int). If you want to use external locking, you lock the object by constructing a `strict_lock<BankAccount>` and then you call `Deposit(int, strict_lock<BankAccount>&)` and `Withdraw(int, strict_lock<BankAccount>&)`. For example, here's the `ATMWithdrawal` function implemented correctly:

```
void ATMWithdrawal(BankAccount& acct, int sum) {
    strict_lock<BankAccount> guard(acct);
    acct.Withdraw(sum, guard);
    acct.Withdraw(2, guard);
}
```

This function has the best of both worlds-it's reasonably safe and efficient at the same time.

It's worth noting that `strict_lock` being a template gives extra safety compared to a straight polymorphic approach. In such a design, BankAccount would derive from a Lockable interface. `strict_lock` would manipulate Lockable references so there's no need for templates. This approach is sound; however, it provides fewer compile-time guarantees. Having a `strict_lock` object would only tell that some object derived from Lockable is currently locked. In the templated approach, having a `strict_lock<BankAccount>` gives a stronger guarantee-it's a `BankAccount` that stays locked.

There's a weasel word in there-I mentioned that ATMWithdrawal is reasonably safe. It's not really safe because there's no enforcement that the `strict_lock<BankAccount>` object locks the appropriate BankAccount object. The type system only ensures that some BankAccount object is locked. For example, consider the following phony implementation of ATMWithdrawal:

```
void ATMWithdrawal(BankAccount& acct, int sum) {
    BankAccount fakeAcct("John Doe", "123-45-6789");
    strict_lock<BankAccount> guard(fakeAcct);
    acct.Withdraw(sum, guard);
    acct.Withdraw(2, guard);
}
```

This code compiles warning-free but obviously doesn't do the right thing-it locks one account and uses another.

It's important to understand what can be enforced within the realm of the C++ type system and what needs to be enforced at runtime. The mechanism we've put in place so far ensures that some BankAccount object is locked during the call to `BankAccount::Withdraw(int, strict_lock<BankAccount>&)`. We must enforce at runtime exactly what object is locked.

If our scheme still needs runtime checks, how is it useful? An unwary or malicious programmer can easily lock the wrong object and manipulate any BankAccount without actually locking it.

First, let's get the malice issue out of the way. C is a language that requires a lot of attention and discipline from the programmer. C++ made some progress by asking a little less of those, while still fundamentally trusting the programmer. These languages are not concerned with malice (as Java is, for example). After all, you can break any C/C++ design simply by using casts "appropriately" (if appropriately is an, er, appropriate word in this context).

The scheme is useful because the likelihood of a programmer forgetting about any locking whatsoever is much greater than the likelihood of a programmer who does remember about locking, but locks the wrong object.

Using `strict_lock` permits compile-time checking of the most common source of errors, and runtime checking of the less frequent problem.

Let's see how to enforce that the appropriate BankAccount object is locked. First, we need to add a member function to the `strict_lock` class template. The `bool strict_lock<T>::owns_lock(Loclable*)` function returns a reference to the locked object.

```
template <class Lockable> class strict_lock {
    ... as before ...
public:
    bool owns_lock(Lockable* mtx) const { return mtx==&obj_; }
};
```

Second, BankAccount needs to use this function compare the locked object against this:

```
class BankAccount {
: public basic_lockable_adapter<boost::recursive_mutex>
    int balance_;
public:
    void Deposit(int amount, strict_lock<BankAccount>& guard) {
        // Externally locked
        if (!guard.owns_lock(*this))
            throw "Locking Error: Wrong Object Locked";
        balance_ += amount;
    }
// ...
};
```

The overhead incurred by the test above is much lower than locking a recursive mutex for the second time.

## Improving External Locking

Now let's assume that BankAccount doesn't use its own locking at all, and has only a thread-neutral implementation:

```
class BankAccount {
    int balance_;
public:
    void Deposit(int amount) {
        balance_ += amount;
    }
    void Withdraw(int amount) {
        balance_ -= amount;
    }
};
```

Now you can use BankAccount in single-threaded and multi-threaded applications alike, but you need to provide your own synchronization in the latter case.

Say we have an AccountManager class that holds and manipulates a BankAccount object:

```
class AccountManager
: public basic_lockable_adapter<boost::mutex>
{
    BankAccount checkingAcct_;
    BankAccount savingsAcct_;
    ...
};
```

Let's also assume that, by design, AccountManager must stay locked while accessing its BankAccount members. The question is, how can we express this design constraint using the C++ type system? How can we state "You have access to this BankAccount object only after locking its parent AccountManager object"?

The solution is to use a little bridge template `externally_locked` that controls access to a BankAccount.

```
template <typename  T, typename Lockable>
class externally_locked {
    BOOST_CONCEPT_ASSERT((LockableConcept<Lockable>));

public:
    externally_locked(T& obj, Lockable& lockable)
        : obj_(obj)
        , lockable_(lockable)
    {}

    externally_locked(Lockable& lockable)
        : obj_()
        , lockable_(lockable)
    {}

    T& get(strict_lock<Lockable>& lock) {

#ifndef BOOST_THREAD_EXTERNALLY_LOCKED_DONT_CHECK_SAME  // define BOOST_THREAD_EXTERN↵
ALLY_LOCKED_DONT_CHECK_SAME if you don't want to check locker check the same lockable
        if (!lock.is_locking(&lockable_)) throw lock_er↵
ror(); run time check throw if not locks the same
#endif
        return obj_;
    }
    void set(const T& obj, Lockable& lockable) {
        obj_ = obj;
        lockable_=lockable;
    }
private:
    T obj_;
    Lockable& lockable_;
};
```

`externally_locked` cloaks an object of type T, and actually provides full access to that object through the get and set member functions, provided you pass a reference to a `strict_lock<Owner>` object.

Instead of making `checkingAcct_` and `savingsAcct_` of type `BankAccount`, `AccountManager` holds objects of type `externally_locked<BankAccount, AccountManager>`:

```
class AccountManager
    : public basic_lockable_adapter<thread_mutex>
{
public:
    typedef basic_lockable_adapter<thread_mutex> lockable_base_type;
    AccountManager()
        : checkingAcct_(*this)
        , savingsAcct_(*this)
    {}
    inline void Checking2Savings(int amount);
    inline void AMoreComplicatedChecking2Savings(int amount);
private:

    externally_locked<BankAccount, AccountManager> checkingAcct_;
    externally_locked<BankAccount, AccountManager> savingsAcct_;
};
```

The pattern is the same as before - to access the BankAccount object cloaked by `checkingAcct_`, you need to call `get`. To call `get`, you need to pass it a `strict_lock<AccountManager>`. The one thing you have to take care of is to not hold pointers or references you obtained by calling `get`. If you do that, make sure that you don't use them after the strict_lock has been destroyed. That is, if you alias the cloaked objects, you're back from "the compiler takes care of that" mode to "you must pay attention" mode.

Typically, you use `externally_locked` as shown below. Suppose you want to execute an atomic transfer from your checking account to your savings account:

```
void AccountManager::Checking2Savings(int amount) {
    strict_lock<AccountManager> guard(*this);
    checkingAcct_.get(guard).Withdraw(amount);
    savingsAcct_.get(guard).Deposit(amount);
}
```

We achieved two important goals. First, the declaration of `checkingAcct_` and `savingsAcct_` makes it clear to the code reader that that variable is protected by a lock on an AccountManager. Second, the design makes it impossible to manipulate the two accounts without actually locking a BankAccount. `externally_locked` is what could be called active documentation.

## Allowing other strict locks

Now imagine that the AccountManager function needs to take a `unique_lock` in order to reduce the critical regions. And at some time it needs to access to the `checkingAcct_`. As `unique_lock` is not a strict lock the following code doesn't compiles:

```
void AccountManager::AMoreComplicatedChecking2Savings(int amount) {
    unique_lock<AccountManager> guard(*this, defer_lock);
    if (some_condition()) {
        guard.lock();
    }
    checkingAcct_.get(guard).Withdraw(amount); // COMPILE ERROR
    savingsAcct_.get(guard).Deposit(amount);  // COMPILE ERROR
    do_something_else();
}
```

We need a way to transfer the ownership from the `unique_lock` to a `strict_lock` the time we are working with `savingsAcct_` and then restore the ownership on `unique_lock`.

```
void AccountManager::AMoreComplicatedChecking2Savings(int amount) {
    unique_lock<AccountManager> guard(*this, defer_lock);
    if (some_condition()) {
        guard1.lock();
    }
    {
        strict_lock<AccountManager> guard(guard1);
        checkingAcct_.get(guard).Withdraw(amount);
        savingsAcct_.get(guard).Deposit(amount);
    }
    guard1.unlock();
}
```

In order to make this code compilable we need to store either a Lockable or a `unique_lock<Lockable>` reference depending on the constructor. Store which kind of reference we have stored,and in the destructor call either to the Lockable `unlock` or restore the ownership.

This seams too complicated to me. Another possibility is to define a nested strict lock class. The drawback is that instead of having only one strict lock we have two and we need either to duplicate every function taking a `strict\_lock` or make these function templates functions. The problem with template functions is that we don't profit anymore of the C++ type system. We must add some static metafunction that check that the Locker parameter is a strict lock. The problem is that we can not really check this or can we?. The `is_strict_lock` metafunction must be specialized by the strict lock developer. We need to belive it "sur parolle". The advantage is that now we can manage with more than two strict locks without changing our code. Ths is really nice.

Now we need to state that both classes are `strict_locks`.

```
template <typename Locker>
struct is_strict_lock : mpl::false_ {};

template <typename Lockable>
struct is_strict_lock<strict_lock<Lockable> > : mpl::true_ {}

template <typename Locker>
struct is_strict_lock<nested_strict_lock<Locker> > : mpl::true_ {}
```

Well let me show how this `nested_strict_lock` class looks like and the impacts on the `externally_locked` class and the `AccountManager::AMoreComplicatedFunction` function.

First `nested_strict_lock` class will store on a temporary lock the `Locker`, and transfer the lock ownership on the constructor. On destruction he will restore the ownership. Note also that the Locker needs to have already a reference to the mutex otherwise an exception is thrown and the use of the `lock_traits`.

```
template <typename Locker >
class nested_strict_lock
    {
      BOOST_CONCEPT_ASSERT((MovableLockerConcept<Locker>));
public:
    typedef typename lockable_type<Locker>::type lockable_type;
    typedef typename syntactic_lock_traits<lockable_type>::lock_error lock_error;

    nested_strict_lock(Locker& lock)
        : lock_(lock)  // Store reference to locker
        , tmp_lock_(lock.move()) // Move ownership to temporaty locker
    {
        #ifndef BOOST_THREAD_STRCIT_LOCKER_DONT_CHECK_OWNERSHIP  // Define BOOST_THREAD_EXTERN↵
ALLY_LOCKED_DONT_CHECK_OWNERSHIP if you don't want to check locker ownership
        if (tmp_lock_.mutex()==0) {
            lock_=tmp_lock_.move(); // Rollback for coherency purposes
            throw lock_error();
        }
        #endif
        if (!tmp_lock_) tmp_lock_.lock(); // ensures it is locked
    }
    ~nested_strict_lock() {
        lock_=tmp_lock_.move(); // Move ownership to nesting locker
    }
    typedef bool (nested_strict_lock::*bool_type)() const;
    operator bool_type() const { return &nested_strict_lock::owns_lock; }
    bool operator!() const { return false; }
    bool owns_lock() const { return true; }
    const lockable_type* mutex() const { return tmp_lock_.mutex(); }
    bool is_locking(lockable_type* l) const { return l==mutex(); }

    BOOST_ADRESS_OF_DELETE(nested_strict_lock)
    BOOST_HEAP_ALLOCATEION_DELETE(nested_strict_lock)
    BOOST_DEFAULT_CONSTRUCTOR_DELETE(nested_strict_lock) 8
    BOOST_COPY_CONSTRUCTOR_DELETE(nested_strict_lock) 9
    BOOST_COPY_ASSIGNEMENT_DELETE(nested_strict_lock) 10

private:
    Locker& lock_;
    Locker tmp_lock_;
};
```

The `externally_locked` get function is now a template function taking a Locker as parameters instead of a `strict_lock`. We can add test in debug mode that ensure that the Lockable object is locked.

```
template <typename  T, typename Lockable>
class externally_locked {
public:
    // ...
    template <class Locker>
    T& get(Locker& lock) {
        BOOST_CONCEPT_ASSERT((StrictLockerConcept<Locker>));

       BOOST_STATIC_ASSERT((is_strict_lock<Locker>::value)); // locker is a strict locker "sur ↵
parolle"
        BOOST_STATIC_ASSERT((is_same<Lockable,
                typename lockable_type<Locker>::type>::value)); // that locks the same type
#ifndef BOOST_THREAD_EXTERNALLY_LOCKED_DONT_CHECK_OWNERSHIP  // define BOOST_THREAD_EXTERN↵
ALLY_LOCKED_NO_CHECK_OWNERSHIP if you don't want to check locker ownership
        if (! lock ) throw lock_error(); // run time check throw if no locked
#endif
#ifndef BOOST_THREAD_EXTERNALLY_LOCKED_DONT_CHECK_SAME
        if (!lock.is_locking(&lockable_)) throw lock_error();
#endif
        return obj_;
    }
};
```

The `AccountManager::AMoreComplicatedFunction` function needs only to replace the `strict_lock` by a `nested_strict_lock`.

```
void AccountManager::AMoreComplicatedChecking2Savings(int amount) {
    unique_lock<AccountManager> guard1(*this);
    if (some_condition()) {
        guard1.lock();
    }
    {
        nested_strict_lock<unique_lock<AccountManager> > guard(guard1);
        checkingAcct_.get(guard).Withdraw(amount);
        savingsAcct_.get(guard).Deposit(amount);
    }
    guard1.unlock();
}
```

## Executing Around a Function

In particular, the library provides some lock factories.

```
template <class Lockable, class Function>
auto with_lock_guard(Lockable& m, Function f) -> decltype(fn())
{
  auto&& _ = boost::make_lock_guard(f);
  f();
}
```

that can be used as

```
int i = with_lock_guard(mtx, {}() -> bool
{
  // access the protected state
  return true;
});
```

# Mutex Concepts

A mutex object facilitates protection against data races and allows thread-safe synchronization of data between threads. A thread obtains ownership of a mutex object by calling one of the lock functions and relinquishes ownership by calling the corresponding unlock function. Mutexes may be either recursive or non-recursive, and may grant simultaneous ownership to one or many threads. **Boost.Thread** supplies recursive and non-recursive mutexes with exclusive ownership semantics, along with a shared ownership (multiple-reader / single-writer) mutex.

**Boost.Thread** supports four basic concepts for lockable objects: `Lockable`, `TimedLockable`, `SharedLockable` and `UpgradeLockable`. Each mutex type implements one or more of these concepts, as do the various lock types.

## `BasicLockable` Concept

```
// #include <boost/thread/lockable_concepts.hpp>

namespace boost
{

  template<typename L>
  class BasicLockable; // EXTENSION
}
```

The `BasicLockable` concept models exclusive ownership. A type `L` meets the `BasicLockable` requirements if the following expressions are well-formed and have the specified semantics (`m` denotes a value of type `L`):

- `m.lock();`
- `m.unlock();`

Lock ownership acquired through a call to `lock()` must be released through a call to `unlock()`.

### `m.lock();`

| | |
|---|---|
| Effects: | The current thread blocks until ownership can be obtained for the current thread. |
| Synchronization: | Prior `unlock()` operations on the same object synchronizes with this operation. |
| Postcondition: | The current thread owns `m`. |
| Return type: | `void`. |
| Throws: | `lock_error` if an error occurs. |
| Error Conditions: | **operation_not_permitted**: if the thread does not have the privilege to perform the operation. |
| | **resource_deadlock_would_occur**: if the implementation detects that a deadlock would occur. |
| | **device_or_resource_busy**: if the mutex is already locked and blocking is not possible. |
| Thread safety: | If an exception is thrown then a lock shall not have been acquired for the current thread. |

### `m.unlock();`

| | |
|---|---|
| Requires: | The current thread owns `m`. |
| Synchronization: | This operation synchronizes with subsequent lock operations that obtain ownership on the same object. |
| Effects: | Releases a lock on `m` by the current thread. |

Return type: void.

Throws: Nothing.

### `is_basic_lockable` trait -- EXTENSION

```
// #include <boost/thread/lockable_traits.hpp>

namespace boost
{
  namespace sync
  {
    template<typename L>
    class is_basic_lockable;// EXTENSION
  }
}
```

Some of the algorithms on mutexes use this trait via SFINAE. If BOOST_THREAD_NO_AUTO_DETECT_MUTEX_TYPES is defined you will need to specialize this traits for the models of BasicLockable you could build.

## `Lockable` Concept

```
// #include <boost/thread/lockable_concepts.hpp>
namespace boost
{
  template<typename L>
  class Lockable;
}
```

A type `L` meets the `Lockable` requirements if it meets the `BasicLockable` requirements and the following expressions are well-formed and have the specified semantics (`m` denotes a value of type `L`):

- `m.try_lock()`

Lock ownership acquired through a call to `try_lock()` must be released through a call to `unlock()`.

#### `m.try_lock()`

Effects: Attempt to obtain ownership for the current thread without blocking.

Synchronization: If `try_lock()` returns true, prior `unlock()` operations on the same object synchronize with this operation.

Note: Since `lock()` does not synchronize with a failed subsequent `try_lock()`, the visibility rules are weak enough that little would be known about the state after a failure, even in the absence of spurious failures.

Return type: `bool`.

Returns: `true` if ownership was obtained for the current thread, `false` otherwise.

Postcondition: If the call returns `true`, the current thread owns the `m`.

Throws: Nothing.

### `is_lockable` trait -- EXTENSION

```
// #include <boost/thread/lockable_traits.hpp>
namespace boost
{
  namespace sync
  {
    template<typename L>
    class is_lockable;// EXTENSION
  }
}
```

Some of the algorithms on mutexes use this trait via SFINAE. If BOOST_THREAD_NO_AUTO_DETECT_MUTEX_TYPES is defined you will need to specialize this traits for the models of Lockable you could build.

## Recursive Lockable Concept

The user could require that the mutex passed to an algorithm is a recursive one. Whether a lockable is recursive or not can not be checked using template meta-programming. This is the motivation for the following trait.

### `is_recursive_mutex_sur_parolle` trait -- EXTENSION

```
// #include <boost/thread/lockable_traits.hpp>

namespace boost
{
  namespace sync
  {
    template<typename L>
    class is_recursive_mutex_sur_parolle: false_type; // EXTENSION
    template<>
    class is_recursive_mutex_sur_parolle<recursive_mutex>: true_type; // EXTENSION
    template<>
    class is_recursive_mutex_sur_parolle<timed_recursive_mutex>: true_type; // EXTENSION
  }
}
```

The trait `is_recursive_mutex_sur_parolle` is `false_type` by default and is specialized for the provide `recursive_mutex` and `timed_recursive_mutex`.

It should be specialized by the user providing other model of recursive lockable.

## `TimedLockable` Concept

```
// #include <boost/thread/lockable_concepts.hpp>

namespace boost
{
  template<typename L>
  class TimedLockable; // EXTENSION
}
```

The `TimedLockable` concept refines the `Lockable` concept to add support for timeouts when trying to acquire the lock.

A type `L` meets the `TimedLockable` requirements if it meets the `Lockable` requirements and the following expressions are well-formed and have the specified semantics.

**Variables:**

- `m` denotes a value of type `L`,
- `rel_time` denotes a value of an instantiation of `chrono::duration`, and
- `abs_time` denotes a value of an instantiation of `chrono::time_point`:

**Expressions:**

- `m.try_lock_for(rel_time)`
- `m.try_lock_until(abs_time)`

Lock ownership acquired through a call to `try_lock_for` or `try_lock_until` must be released through a call to `unlock`.

**`m.try_lock_until(abs_time)`**

| | |
|---|---|
| Effects: | Attempt to obtain ownership for the current thread. Blocks until ownership can be obtained, or the specified time is reached. If the specified time has already passed, behaves as `try_lock()`. |
| Synchronization: | If `try_lock_until()` returns true, prior `unlock()` operations on the same object synchronize with this operation. |
| Return type: | `bool`. |
| Returns: | `true` if ownership was obtained for the current thread, `false` otherwise. |
| Postcondition: | If the call returns `true`, the current thread owns `m`. |
| Throws: | Nothing. |

**`m.try_lock_for(rel_time)`**

| | |
|---|---|
| Effects: | As-if `try_lock_until(chrono::steady_clock::now() + rel_time)`. |
| Synchronization: | If `try_lock_for()` returns true, prior `unlock()` operations on the same object synchronize with this operation. |

### Warning

DEPRECATED since 4.00. The following expressions were required on version 2, but are now deprecated.

Available only up to Boost 1.58.

Use instead `try_lock_for`, `try_lock_until`.

**Variables:**

- `rel_time` denotes a value of an instantiation of an unspecified `DurationType` arithmetic compatible with `boost::system_time`, and
- `abs_time` denotes a value of an instantiation of `boost::system_time`:

**Expressions:**

- `m.timed_lock(rel_time)`
- `m.timed_lock(abs_time)`

Lock ownership acquired through a call to `timed_lock()` must be released through a call to `unlock()`.

**`m.timed_lock(abs_time)`**

Effects: Attempt to obtain ownership for the current thread. Blocks until ownership can be obtained, or the specified time is reached. If the specified time has already passed, behaves as `try_lock()`.

Returns: `true` if ownership was obtained for the current thread, `false` otherwise.

Postcondition: If the call returns `true`, the current thread owns `m`.

Throws: `lock_error` if an error occurs.

**`m.timed_lock(rel_time)`**

Effects: As-if `timed_lock(boost::get_system_time()+rel_time)`.

## `SharedLockable` Concept -- EXTENSION

```
// #include <boost/thread/lockable_concepts.hpp>

namespace boost
{
  template<typename L>
  class SharedLockable;  // EXTENSION
}
```

The `SharedLockable` concept is a refinement of the `TimedLockable` concept that allows for *shared ownership* as well as *exclusive ownership*. This is the standard multiple-reader / single-write model: at most one thread can have exclusive ownership, and if any thread does have exclusive ownership, no other threads can have shared or exclusive ownership. Alternatively, many threads may have shared ownership.

A type `L` meets the `SharedLockable` requirements if it meets the `TimedLockable` requirements and the following expressions are well-formed and have the specified semantics.

**Variables:**

- `m` denotes a value of type `L`,
- `rel_time` denotes a value of an instantiation of `chrono::duration`, and
- `abs_time` denotes a value of an instantiation of `chrono::time_point`:

**Expressions:**

- `m.lock_shared()();`
- `m.try_lock_shared()`
- `m.try_lock_shared_for(rel_time)`
- `m.try_lock_shared_until(abs_time)`
- `m.unlock_shared()();`

Lock ownership acquired through a call to `lock_shared()`, `try_lock_shared()`, `try_lock_shared_for` or `try_lock_shared_until` must be released through a call to `unlock_shared()`.

**`m.lock_shared()`**

Effects: The current thread blocks until shared ownership can be obtained for the current thread.

Postcondition: The current thread has shared ownership of `m`.

Throws: `lock_error` if an error occurs.

**`m.try_lock_shared()`**

Effects: Attempt to obtain shared ownership for the current thread without blocking.

Returns: `true` if shared ownership was obtained for the current thread, `false` otherwise.

Postcondition: If the call returns `true`, the current thread has shared ownership of `m`.

Throws: `lock_error` if an error occurs.

**`m.try_lock_shared_for(rel_time)`**

Effects: Attempt to obtain shared ownership for the current thread. Blocks until shared ownership can be obtained, or the specified duration is elapsed. If the specified duration is already elapsed, behaves as `try_lock_shared()`.

Returns: `true` if shared ownership was acquired for the current thread, `false` otherwise.

Postcondition: If the call returns `true`, the current thread has shared ownership of `m`.

Throws: `lock_error` if an error occurs.

**`m.try_lock_shared_until(abs_time))`**

Effects: Attempt to obtain shared ownership for the current thread. Blocks until shared ownership can be obtained, or the specified time is reached. If the specified time has already passed, behaves as `try_lock_shared()`.

Returns: `true` if shared ownership was acquired for the current thread, `false` otherwise.

Postcondition: If the call returns `true`, the current thread has shared ownership of `m`.

Throws: `lock_error` if an error occurs.

**`m.unlock_shared()`**

Precondition: The current thread has shared ownership of `m`.

Effects: Releases shared ownership of `m` by the current thread.

Postcondition: The current thread no longer has shared ownership of `m`.

Throws: Nothing

## Warning

DEPRECATED since 3.00. The following expressions were required on version 2, but are now deprecated.

Available only up to Boost 1.56.

Use instead `try_lock_shared_for`, `try_lock_shared_until`.

**Variables:**

- `abs_time` denotes a value of an instantiation of `boost::system_time`:

**Expressions:**

- `m.timed_lock_shared(abs_time);`

Lock ownership acquired through a call to `timed_lock_shared()` must be released through a call to `unlock_shared()`.

**`m.timed_lock_shared(abs_time)`**

| | |
|---|---|
| Effects: | Attempt to obtain shared ownership for the current thread. Blocks until shared ownership can be obtained, or the specified time is reached. If the specified time has already passed, behaves as `try_lock_shared()`. |
| Returns: | `true` if shared ownership was acquired for the current thread, `false` otherwise. |
| Postcondition: | If the call returns `true`, the current thread has shared ownership of `m`. |
| Throws: | `lock_error` if an error occurs. |

## `UpgradeLockable` Concept -- EXTENSION

```
// #include <boost/thread/lockable_concepts.hpp>

namespace boost
{
  template<typename L>
  class UpgradeLockable; // EXTENSION
}
```

The `UpgradeLockable` concept is a refinement of the `SharedLockable` concept that allows for *upgradable ownership* as well as *shared ownership* and *exclusive ownership*. This is an extension to the multiple-reader / single-write model provided by the `SharedLockable` concept: a single thread may have *upgradable ownership* at the same time as others have *shared ownership*. The thread with *upgradable ownership* may at any time attempt to upgrade that ownership to *exclusive ownership*. If no other threads have shared ownership, the upgrade is completed immediately, and the thread now has *exclusive ownership*, which must be relinquished by a call to `unlock()`, just as if it had been acquired by a call to `lock()`.

If a thread with *upgradable ownership* tries to upgrade whilst other threads have *shared ownership*, the attempt will fail and the thread will block until *exclusive ownership* can be acquired.

Ownership can also be *downgraded* as well as *upgraded*: exclusive ownership of an implementation of the `UpgradeLockable` concept can be downgraded to upgradable ownership or shared ownership, and upgradable ownership can be downgraded to plain shared ownership.

A type `L` meets the `UpgradeLockable` requirements if it meets the `SharedLockable` requirements and the following expressions are well-formed and have the specified semantics.

**Variables:**

- `m` denotes a value of type `L`,
- `rel_time` denotes a value of an instantiation of `chrono::duration`, and
- `abs_time` denotes a value of an instantiation of `chrono::time_point`:

**Expressions:**

- `m.lock_upgrade();`
- `m.unlock_upgrade()`
- `m.try_lock_upgrade()`

- `m.try_lock_upgrade_for(rel_time)`
- `m.try_lock_upgrade_until(abs_time)`
- `m.unlock_and_lock_shared()`
- `m.unlock_and_lock_upgrade();`
- `m.unlock_upgrade_and_lock();`
- `m.try_unlock_upgrade_and_lock()`
- `m.try_unlock_upgrade_and_lock_for(rel_time)`
- `m.try_unlock_upgrade_and_lock_until(abs_time)`
- `m.unlock_upgrade_and_lock_shared();`

If `BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION is defined the following expressions are also required:

- `m.try_unlock_shared_and_lock();`
- `m.try_unlock_shared_and_lock_for(rel_time);`
- `m.try_unlock_shared_and_lock_until(abs_time);`
- `m.try_unlock_shared_and_lock_upgrade();`
- `m.try_unlock_shared_and_lock_upgrade_for(rel_time);`
- `m.try_unlock_shared_and_lock_upgrade_until(abs_time);`

Lock ownership acquired through a call to `lock_upgrade()` must be released through a call to `unlock_upgrade()`. If the ownership type is changed through a call to one of the `unlock_xxx_and_lock_yyy()` functions, ownership must be released through a call to the unlock function corresponding to the new level of ownership.

#### `m.lock_upgrade()`

| | |
|---|---|
| Precondition: | The calling thread has no ownership of the mutex. |
| Effects: | The current thread blocks until upgrade ownership can be obtained for the current thread. |
| Postcondition: | The current thread has upgrade ownership of `m`. |
| Synchronization: | Prior `unlock_upgrade()` operations on the same object synchronize with this operation. |
| Throws: | `lock_error` if an error occurs. |

#### `m.unlock_upgrade()`

| | |
|---|---|
| Precondition: | The current thread has upgrade ownership of `m`. |
| Effects: | Releases upgrade ownership of `m` by the current thread. |
| Postcondition: | The current thread no longer has upgrade ownership of `m`. |
| Synchronization: | This operation synchronizes with subsequent lock operations that obtain ownership on the same object. |
| Throws: | Nothing |

### m.try_lock_upgrade()

| | |
|---|---|
| Precondition: | The calling thread has no ownership of the mutex. |
| Effects: | Attempts to obtain upgrade ownership of the mutex for the calling thread without blocking. If upgrade ownership is not obtained, there is no effect and try_lock_upgrade() immediately returns. |
| Returns: | `true` if upgrade ownership was acquired for the current thread, `false` otherwise. |
| Postcondition: | If the call returns `true`, the current thread has upgrade ownership of `m`. |
| Synchronization: | If `try_lock_upgrade()` returns true, prior `unlock_upgrade()` operations on the same object synchronize with this operation. |
| Throws: | Nothing |

### m.try_lock_upgrade_for(rel_time)

| | |
|---|---|
| Precondition: | The calling thread has no ownership of the mutex. |
| Effects: | If the tick period of `rel_time` is not exactly convertible to the native tick period, the duration shall be rounded up to the nearest native tick period. Attempts to obtain upgrade lock ownership for the calling thread within the relative timeout specified by `rel_time`. If the time specified by `rel_time` is less than or equal to `rel_time.zero()`, the function attempts to obtain ownership without blocking (as if by calling `try_lock_upgrade()`). The function returns within the timeout specified by `rel_time` only if it has obtained upgrade ownership of the mutex object. |
| Returns: | `true` if upgrade ownership was acquired for the current thread, `false` otherwise. |
| Postcondition: | If the call returns `true`, the current thread has upgrade ownership of `m`. |
| Synchronization: | If `try_lock_upgrade_for(rel_time)` returns true, prior `unlock_upgrade()` operations on the same object synchronize with this operation. |
| Throws: | Nothing |
| Notes: | Available only if `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform |

### m.try_lock_upgrade_until(abs_time)

| | |
|---|---|
| Precondition: | The calling thread has no ownership of the mutex. |
| Effects: | The function attempts to obtain upgrade ownership of the mutex. If `abs_time` has already passed, the function attempts to obtain upgrade ownership without blocking (as if by calling `try_lock_upgrade()`). The function returns before the absolute timeout specified by `abs_time` only if it has obtained upgrade ownership of the mutex object. |
| Returns: | `true` if upgrade ownership was acquired for the current thread, `false` otherwise. |
| Postcondition: | If the call returns `true`, the current thread has upgrade ownership of `m`. |
| Synchronization: | If `try_lock_upgrade_until(abs_time)` returns true, prior `unlock_upgrade()` operations on the same object synchronize with this operation. |
| Throws: | Nothing |
| Notes: | Available only if `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform |

### m.try_unlock_shared_and_lock()

| | |
|---|---|
| Precondition: | The calling thread must hold a shared lock on the mutex. |
| Effects: | The function attempts to atomically convert the ownership from shared to exclusive for the calling thread without blocking. For this conversion to be successful, this thread must be the only thread holding any ownership of the lock. If the conversion is not successful, the shared ownership of m is retained. |
| Returns: | `true` if exclusive ownership was acquired for the current thread, `false` otherwise. |
| Postcondition: | If the call returns `true`, the current thread has exclusive ownership of `m`. |
| Synchronization: | If `try_unlock_shared_and_lock()` returns true, prior `unlock()` and subsequent lock operations on the same object synchronize with this operation. |
| Throws: | Nothing |
| Notes: | Available only if `BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION` and `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform |

### m.try_unlock_shared_and_lock_for(rel_time)

| | |
|---|---|
| Precondition: | The calling thread shall hold a shared lock on the mutex. |
| Effects: | If the tick period of `rel_time` is not exactly convertible to the native tick period, the duration shall be rounded up to the nearest native tick period. The function attempts to atomically convert the ownership from shared to exclusive for the calling thread within the relative timeout specified by `rel_time`. If the time specified by `rel_time` is less than or equal to `rel_time.zero()`, the function attempts to obtain exclusive ownership without blocking (as if by calling `try_unlock_shared_and_lock()`). The function shall return within the timeout specified by `rel_time` only if it has obtained exclusive ownership of the mutex object. For this conversion to be successful, this thread must be the only thread holding any ownership of the lock at the moment of conversion. If the conversion is not successful, the shared ownership of the mutex is retained. |
| Returns: | `true` if exclusive ownership was acquired for the current thread, `false` otherwise. |
| Postcondition: | If the call returns `true`, the current thread has exclusive ownership of `m`. |
| Synchronization: | If `try_unlock_shared_and_lock_for(rel_time)` returns true, prior `unlock()` and subsequent lock operations on the same object synchronize with this operation. |
| Throws: | Nothing |
| Notes: | Available only if `BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION` and `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform |

### m.try_unlock_shared_and_lock_until(abs_time)

| | |
|---|---|
| Precondition: | The calling thread shall hold a shared lock on the mutex. |
| Effects: | The function attempts to atomically convert the ownership from shared to exclusive for the calling thread within the absolute timeout specified by `abs_time`. If `abs_time` has already passed, the function attempts to obtain exclusive ownership without blocking (as if by calling `try_unlock_shared_and_lock()`). The function shall return before the absolute timeout specified by `abs_time` only if it has obtained exclusive ownership of the mutex object. For this conversion to be successful, this thread must be the only thread holding any ownership of the lock at the moment of conversion. If the conversion is not successful, the shared ownership of the mutex is retained. |
| Returns: | `true` if exclusive ownership was acquired for the current thread, `false` otherwise. |

Postcondition: If the call returns `true`, the current thread has exclusive ownership of `m`.

Synchronization: If `try_unlock_shared_and_lock_until(rel_time)` returns true, prior `unlock()` and subsequent lock operations on the same object synchronize with this operation.

Throws: Nothing

Notes: Available only if `BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION` and `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform

### `m.unlock_and_lock_shared()`

Precondition: The calling thread shall hold an exclusive lock on `m`.

Effects: Atomically converts the ownership from exclusive to shared for the calling thread.

Postcondition: The current thread has shared ownership of `m`.

Synchronization: This operation synchronizes with subsequent lock operations that obtain ownership of the same object.

Throws: Nothing

### `m.try_unlock_shared_and_lock_upgrade()`

Precondition: The calling thread shall hold a shared lock on the mutex.

Effects: The function attempts to atomically convert the ownership from shared to upgrade for the calling thread without blocking. For this conversion to be successful, there must be no thread holding upgrade ownership of this object. If the conversion is not successful, the shared ownership of the mutex is retained.

Returns: `true` if upgrade ownership was acquired for the current thread, `false` otherwise.

Postcondition: If the call returns `true`, the current thread has upgrade ownership of `m`.

Synchronization: If `try_unlock_shared_and_lock_upgrade()` returns true, prior `unlock_upgrade()` and subsequent lock operations on the same object synchronize with this operation.

Throws: Nothing

Notes: Available only if `BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION` and `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform

### `m.try_unlock_shared_and_lock_upgrade_for(rel_time)`

Precondition: The calling thread shall hold a shared lock on the mutex.

Effects: If the tick period of `rel_time` is not exactly convertible to the native tick period, the duration shall be rounded up to the nearest native tick period. The function attempts to atomically convert the ownership from shared to upgrade for the calling thread within the relative timeout specified by `rel_time`. If the time specified by `rel_time` is less than or equal to `rel_time.zero()`, the function attempts to obtain upgrade ownership without blocking (as if by calling `try_unlock_shared_and_lock_upgrade()`). The function shall return within the timeout specified by `rel_time` only if it has obtained exclusive ownership of the mutex object. For this conversion to be successful, there must be no thread holding upgrade ownership of this object at the moment of conversion. If the conversion is not successful, the shared ownership of m is retained.

Returns: `true` if upgrade ownership was acquired for the current thread, `false` otherwise.

Postcondition: If the call returns `true`, the current thread has upgrade ownership of `m`.

Synchronization: If try_unlock_shared_and_lock_upgrade_for(rel_time) returns true, prior unlock_upgrade() and subsequent lock operations on the same object synchronize with this operation.

Throws: Nothing

Notes: Available only if BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION and BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN is defined on Windows platform

### m.try_unlock_shared_and_lock_upgrade_until(abs_time)

Precondition: The calling thread shall hold a shared lock on the mutex.

Effects: The function attempts to atomically convert the ownership from shared to upgrade for the calling thread within the absolute timeout specified by abs_time. If abs_time has already passed, the function attempts to obtain upgrade ownership without blocking (as if by calling try_unlock_shared_and_lock_upgrade()). The function shall return before the absolute timeout specified by abs_time only if it has obtained upgrade ownership of the mutex object. For this conversion to be successful, there must be no thread holding upgrade ownership of this object at the moment of conversion. If the conversion is not successful, the shared ownership of the mutex is retained.

Returns: true if upgrade ownership was acquired for the current thread, false otherwise.

Postcondition: If the call returns true, the current thread has upgrade ownership of m.

Synchronization: If try_unlock_shared_and_lock_upgrade_until(rel_time) returns true, prior unlock_upgrade() and subsequent lock operations on the same object synchronize with this operation.

Throws: Nothing

Notes: Available only if BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION and BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN is defined on Windows platform

### m.unlock_and_lock_upgrade()

Precondition: The current thread has exclusive ownership of m.

Effects: Atomically releases exclusive ownership of m by the current thread and acquires upgrade ownership of m without blocking.

Postcondition: The current thread has upgrade ownership of m.

Synchronization: This operation synchronizes with subsequent lock operations that obtain ownership of the same object.

Throws: Nothing

### m.unlock_upgrade_and_lock()

Precondition: The current thread has upgrade ownership of m.

Effects: Atomically releases upgrade ownership of m by the current thread and acquires exclusive ownership of m. If any other threads have shared ownership, blocks until exclusive ownership can be acquired.

Postcondition: The current thread has exclusive ownership of m.

Synchronization: This operation synchronizes with prior unlock_shared()() and subsequent lock operations that obtain ownership of the same object.

Throws: Nothing

### m.try_unlock_upgrade_and_lock()

| | |
|---|---|
| Precondition: | The calling thread shall hold a upgrade lock on the mutex. |
| Effects: | The function attempts to atomically convert the ownership from upgrade to exclusive for the calling thread without blocking. For this conversion to be successful, this thread must be the only thread holding any ownership of the lock. If the conversion is not successful, the upgrade ownership of m is retained. |
| Returns: | `true` if exclusive ownership was acquired for the current thread, `false` otherwise. |
| Postcondition: | If the call returns `true`, the current thread has exclusive ownership of `m`. |
| Synchronization: | If `try_unlock_upgrade_and_lock()` returns true, prior `unlock()` and subsequent lock operations on the same object synchronize with this operation. |
| Throws: | Nothing |
| Notes: | Available only if `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform |

### m.try_unlock_upgrade_and_lock_for(rel_time)

| | |
|---|---|
| Precondition: | The calling thread shall hold a upgrade lock on the mutex. |
| Effects: | If the tick period of `rel_time` is not exactly convertible to the native tick period, the duration shall be rounded up to the nearest native tick period. The function attempts to atomically convert the ownership from upgrade to exclusive for the calling thread within the relative timeout specified by `rel_time`. If the time specified by `rel_time` is less than or equal to `rel_time.zero()`, the function attempts to obtain exclusive ownership without blocking (as if by calling `try_unlock_upgrade_and_lock()`). The function shall return within the timeout specified by `rel_time` only if it has obtained exclusive ownership of the mutex object. For this conversion to be successful, this thread shall be the only thread holding any ownership of the lock at the moment of conversion. If the conversion is not successful, the upgrade ownership of m is retained. |
| Returns: | `true` if exclusive ownership was acquired for the current thread, `false` otherwise. |
| Postcondition: | If the call returns `true`, the current thread has exclusive ownership of `m`. |
| Synchronization: | If `try_unlock_upgrade_and_lock_for(rel_time)` returns true, prior `unlock()` and subsequent lock operations on the same object synchronize with this operation. |
| Throws: | Nothing |
| Notes: | Available only if `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform |

### m.try_unlock_upgrade_and_lock_until(abs_time)

| | |
|---|---|
| Precondition: | The calling thread shall hold a upgrade lock on the mutex. |
| Effects: | The function attempts to atomically convert the ownership from upgrade to exclusive for the calling thread within the absolute timeout specified by `abs_time`. If `abs_time` has already passed, the function attempts to obtain exclusive ownership without blocking (as if by calling `try_unlock_upgrade_and_lock()`). The function shall return before the absolute timeout specified by `abs_time` only if it has obtained exclusive ownership of the mutex object. For this conversion to be successful, this thread shall be the only thread holding any ownership of the lock at the moment of conversion. If the conversion is not successful, the upgrade ownership of m is retained. |
| Returns: | `true` if exclusive ownership was acquired for the current thread, `false` otherwise. |

Postcondition: If the call returns `true`, the current thread has exclusive ownership of `m`.

Synchronization: If `try_unlock_upgrade_and_lock_for(rel_time)` returns true, prior `unlock()` and subsequent lock operations on the same object synchronize with this operation.

Throws: Nothing

Notes: Available only if `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform

#### `m.unlock_upgrade_and_lock_shared()`

Precondition: The current thread has upgrade ownership of `m`.

Effects: Atomically releases upgrade ownership of `m` by the current thread and acquires shared ownership of `m` without blocking.

Postcondition: The current thread has shared ownership of `m`.

Synchronization: This operation synchronizes with prior `unlock_shared()` and subsequent lock operations that obtain ownership of the same object.

Throws: Nothing

# Lock Options

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/locks_options.hpp>

namespace boost
{
  struct defer_lock_t {};
  struct try_to_lock_t {};
  struct adopt_lock_t {};
  constexpr defer_lock_t defer_lock;
  constexpr try_to_lock_t try_to_lock;
  constexpr adopt_lock_t adopt_lock;
```

## Lock option tags

```
#include <boost/thread/locks.hpp>
#include <boost/thread/locks_options.hpp>

struct defer_lock_t {};
struct try_to_lock_t {};
struct adopt_lock_t {};
const defer_lock_t defer_lock;
const try_to_lock_t try_to_lock;
const adopt_lock_t adopt_lock;
```

These tags are used in scoped locks constructors to specify a specific behavior.

- `defer_lock_t`: is used to construct the scoped lock without locking it.
- `try_to_lock_t`: is used to construct the scoped lock trying to lock it.
- `adopt_lock_t`: is used to construct the scoped lock without locking it but adopting ownership.

# Lock Guard

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/lock_guard.hpp>

namespace boost
{

  template<typename Lockable>
  class lock_guard
#if ! defined BOOST_THREAD_NO_MAKE_LOCK_GUARD
  template <typename Lockable>
  lock_guard<Lockable> make_lock_guard(Lockable& mtx); // EXTENSION
  template <typename Lockable>
  lock_guard<Lockable> make_lock_guard(Lockable& mtx, adopt_lock_t); // EXTENSION
#endif
}
```

## Class template `lock_guard`

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/lock_guard.hpp>

template<typename Lockable>
class lock_guard
{
public:
    explicit lock_guard(Lockable& m_);
    lock_guard(Lockable& m_,boost::adopt_lock_t);

    ~lock_guard();
};
```

`boost::lock_guard` is very simple: on construction it acquires ownership of the implementation of the `Lockable` concept supplied as the constructor parameter. On destruction, the ownership is released. This provides simple RAII-style locking of a `Lockable` object, to facilitate exception-safe locking and unlocking. In addition, the `lock_guard(Lockable & m,boost::adopt_lock_t)` constructor allows the `boost::lock_guard` object to take ownership of a lock already held by the current thread.

#### `lock_guard(Lockable & m)`

Effects: Stores a reference to `m`. Invokes `m.lock()`.

Throws: Any exception thrown by the call to `m.lock()`.

#### `lock_guard(Lockable & m,boost::adopt_lock_t)`

Precondition: The current thread owns a lock on `m` equivalent to one obtained by a call to `m.lock()`.

Effects: Stores a reference to `m`. Takes ownership of the lock state of `m`.

Throws: Nothing.

#### `~lock_guard()`

Effects: Invokes `m.unlock()` on the `Lockable` object passed to the constructor.

Throws: Nothing.

## Non Member Function `make_lock_guard`

```
template <typename Lockable>
lock_guard<Lockable> make_lock_guard(Lockable& m); // EXTENSION
```

Returns: a lock_guard as if initialized with `{m}`.

Throws: Any exception thrown by the call to `m.lock()`.

## Non Member Function `make_lock_guard`

```
template <typename Lockable>
lock_guard<Lockable> make_lock_guard(Lockable& m, adopt_lock_t); // EXTENSION
```

Returns: a lock_guard as if initialized with `{m, adopt_lock}`.

Throws: Any exception thrown by the call to `m.lock()`.

# Lock Concepts

## StrictLock -- EXTENSION

```
// #include <boost/thread/lock_concepts.hpp>

namespace boost
{

  template<typename Lock>
  class StrictLock;
}
```

A StrictLock is a lock that ensures that the associated mutex is locked during the lifetime if the lock.

A type `L` meets the StrictLock requirements if the following expressions are well-formed and have the specified semantics

- `L::mutex_type`
- `is_strict_lock<L>`
- `cl.owns_lock(m);`

and BasicLockable<L::mutex_type>

where

- `cl` denotes a value of type `L const&`,
- `m` denotes a value of type `L::mutex_type const*`,

#### `L::mutex_type`

The type L::mutex_type denotes the mutex that is locked by this lock.

### `is_strict_lock_sur_parolle<L>`

As the semantic "ensures that the associated mutex is locked during the lifetime if the lock. " can not be described by syntactic requirements a `is_strict_lock_sur_parolle` trait must be specialized by the user defining the lock so that the following assertion is true:

```
is_strict_lock_sur_parolle<L>::value == true
```

### `cl.owns_lock(m);`

Return Type: `bool`

Returns: Whether the strict lock is locking the mutex `m`

Throws: Nothing.

## Models

The following classes are models of `StrictLock`:

- strict_lock: ensured by construction,
- nested_strict_lock: ensured by construction,
- `boost::lock_guard`: "sur parolle" as the user could use adopt_lock_t constructor overload without having locked the mutex.

# Lock Types

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/lock_types.hpp>

namespace boost
{

  template<typename Lockable>
  class unique_lock;
  template<typename Mutex>
  void swap(unique_lock <Mutex>& lhs, unique_lock <Mutex>& rhs);
  template<typename Lockable>
  class shared_lock; // EXTENSION
  template<typename Mutex>
  void swap(shared_lock<Mutex>& lhs,shared_lock<Mutex>& rhs); // EXTENSION
  template<typename Lockable>
  class upgrade_lock; // EXTENSION
  template<typename Mutex>
  void swap(upgrade_lock <Mutex>& lhs, upgrade_lock <Mutex>& rhs); // EXTENSION
  template <class Mutex>
  class upgrade_to_unique_lock; // EXTENSION
}
```

## Class template `unique_lock`

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/lock_types.hpp>

template<typename Lockable>
class unique_lock
{
public:
    typedef Lockable mutex_type;
    unique_lock() noexcept;
    explicit unique_lock(Lockable& m_);
    unique_lock(Lockable& m_,adopt_lock_t);
    unique_lock(Lockable& m_,defer_lock_t) noexcept;
    unique_lock(Lockable& m_,try_to_lock_t);

#ifdef BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION
    unique_lock(shared_lock<mutex_type>&& sl, try_to_lock_t)
    template <class Clock, class Duration>
    unique_lock(shared_lock<mutex_type>&& sl,
                const chrono::time_point<Clock, Duration>& abs_time);
    template <class Rep, class Period>
    unique_lock(shared_lock<mutex_type>&& sl,
                const chrono::duration<Rep, Period>& rel_time)
#endif

    template <class Clock, class Duration>
    unique_lock(Mutex& mtx, const chrono::time_point<Clock, Duration>& t);
    template <class Rep, class Period>
    unique_lock(Mutex& mtx, const chrono::duration<Rep, Period>& d);
    ~unique_lock();

    unique_lock(unique_lock const&) = delete;
    unique_lock& operator=(unique_lock const&) = delete;
    unique_lock(unique_lock<Lockable>&& other) noexcept;
    explicit unique_lock(upgrade_lock<Lockable>&& other) noexcept;

    unique_lock& operator=(unique_lock<Lockable>&& other) noexcept;

    void swap(unique_lock& other) noexcept;
    Lockable* release() noexcept;

    void lock();
    bool try_lock();

    template <class Rep, class Period>
    bool try_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_until(const chrono::time_point<Clock, Duration>& abs_time);

    void unlock();

    explicit operator bool() const noexcept;
    bool owns_lock() const noexcept;

    Lockable* mutex() const noexcept;

#if defined BOOST_THREAD_USE_DATE_TIME || defined BOOST_THREAD_DONT_USE_CHRONO
    unique_lock(Lockable& m_,system_time const& target_time);
```

```
    template<typename TimeDuration>
    bool timed_lock(TimeDuration const& relative_time);
    bool timed_lock(::boost::system_time const& absolute_time);
#endif

};
```

`boost::unique_lock` is more complex than `boost::lock_guard`: not only does it provide for RAII-style locking, it also allows for deferring acquiring the lock until the `lock()` member function is called explicitly, or trying to acquire the lock in a non-blocking fashion, or with a timeout. Consequently, `unlock()` is only called in the destructor if the lock object has locked the `Lockable` object, or otherwise adopted a lock on the `Lockable` object.

Specializations of `boost::unique_lock` model the `TimedLockable` concept if the supplied `Lockable` type itself models `TimedLockable` concept (e.g. `boost::unique_lock<boost::timed_mutex>`), or the `Lockable` concept if the supplied `Lockable` type itself models `Lockable` concept (e.g. `boost::unique_lock<boost::mutex>`), or the `BasicLockable` concept if the supplied `Lockable` type itself models `BasicLockable` concept.

An instance of `boost::unique_lock` is said to *own* the lock state of a `Lockable` `m` if `mutex()` returns a pointer to `m` and `owns_lock()` returns `true`. If an object that *owns* the lock state of a `Lockable` object is destroyed, then the destructor will invoke `mutex()->unlock()`.

The member functions of `boost::unique_lock` are not thread-safe. In particular, `boost::unique_lock` is intended to model the ownership of a `Lockable` object by a particular thread, and the member functions that release ownership of the lock state (including the destructor) must be called by the same thread that acquired ownership of the lock state.

#### `unique_lock()`

Effects: Creates a lock object with no associated mutex.

Postcondition: `owns_lock()` returns `false`. `mutex()` returns `NULL`.

Throws: Nothing.

#### `unique_lock(Lockable & m)`

Effects: Stores a reference to `m`. Invokes `m.lock()`.

Postcondition: `owns_lock()` returns `true`. `mutex()` returns `&m`.

Throws: Any exception thrown by the call to `m.lock()`.

#### `unique_lock(Lockable & m,boost::adopt_lock_t)`

Precondition: The current thread owns an exclusive lock on `m`.

Effects: Stores a reference to `m`. Takes ownership of the lock state of `m`.

Postcondition: `owns_lock()` returns `true`. `mutex()` returns `&m`.

Throws: Nothing.

#### `unique_lock(Lockable & m,boost::defer_lock_t)`

Effects: Stores a reference to `m`.

Postcondition: `owns_lock()` returns `false`. `mutex()` returns `&m`.

Throws: Nothing.

#### unique_lock(Lockable & m,boost::try_to_lock_t)

Effects: Stores a reference to m. Invokes m.try_lock(), and takes ownership of the lock state if the call returns true.

Postcondition: mutex() returns &m. If the call to try_lock() returned true, then owns_lock() returns true, otherwise owns_lock() returns false.

Throws: Nothing.

#### unique_lock(shared_lock<mutex_type>&& sl, try_to_lock_t)

Requires: The supplied Mutex type must implement try_unlock_shared_and_lock().

Effects: Constructs an object of type boost::unique_lock. Let pm be the pointer to the mutex and owns the ownership state. Initializes pm with nullptr and owns with false. If sl. owns_lock()() returns false, sets pm to the return value of sl.release(). Else sl. owns_lock()() returns true, and in this case if sl.mutex()->try_unlock_shared_and_lock() returns true, sets pm to the value returned by sl.release() and sets owns to true.

Note: If sl.owns_lock() returns true and sl.mutex()->try_unlock_shared_and_lock() returns false, sl is not modified.

Throws: Nothing.

Notes: Available only if BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION and BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN is defined on Windows platform

#### unique_lock(shared_lock<mutex_type>&&, const chrono::time_point<Clock, Duration>&)

```
template <class Clock, class Duration>
unique_lock(shared_lock<mutex_type>&& sl,
            const chrono::time_point<Clock, Duration>& abs_time);
```

Requires: The supplied Mutex type shall implement try_unlock_shared_and_lock_until(abs_time).

Effects: Constructs an object of type boost::unique_lock, initializing pm with nullptr and owns with false. If sl. owns_lock()() returns false, sets pm to the return value of sl.release(). Else sl. owns_lock()() returns true, and in this case if sl.mutex()->try_unlock_shared_and_lock_until(abs_time) returns true, sets pm to the value returned by sl.release() and sets owns to true.

Note: If sl.owns_lock() returns true and sl.mutex()-> try_unlock_shared_and_lock_until(abs_time) returns false, sl is not modified.

Throws: Nothing.

Notes: Available only if BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION and BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN is defined on Windows platform

#### unique_lock(shared_lock<mutex_type>&&, const chrono::duration<Rep, Period>&)

```
template <class Rep, class Period>
unique_lock(shared_lock<mutex_type>&& sl,
            const chrono::duration<Rep, Period>& rel_time)
```

Requires: The supplied Mutex type shall implement try_unlock_shared_and_lock_for(rel_time).

Effects: Constructs an object of type boost::unique_lock, initializing pm with nullptr and owns with false. If sl. owns_lock()() returns false, sets pm to the return value of sl.release(). Else sl.owns_lock()

returns `true`, and in this case if `sl.mutex()->` `try_unlock_shared_and_lock_for(rel_time)` returns `true`, sets `pm` to the value returned by `sl.release()` and sets `owns` to `true`.

Note: If `sl.owns_lock()` returns `true` and `sl.mutex()->` `try_unlock_shared_and_lock_for(rel_time)` returns `false`, `sl` is not modified.

Postcondition: .

Throws: Nothing.

Notes: Available only if `BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION` and `BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN` is defined on Windows platform

#### `unique_lock(Lockable & m,boost::system_time const& abs_time)`

Effects: Stores a reference to `m`. Invokes `m.timed_lock(abs_time)`, and takes ownership of the lock state if the call returns `true`.

Postcondition: `mutex()` returns `&m`. If the call to `timed_lock()` returned `true`, then `owns_lock()` returns `true`, otherwise `owns_lock()` returns `false`.

Throws: Any exceptions thrown by the call to `m.timed_lock(abs_time)`.

#### `template <class Clock, class Duration> unique_lock(Lockable & m,const chrono::time_point<Clock, Duration>& abs_time)`

Effects: Stores a reference to `m`. Invokes `m.try_lock_until(abs_time)`, and takes ownership of the lock state if the call returns `true`.

Postcondition: `mutex()` returns `&m`. If the call to `try_lock_until` returned `true`, then `owns_lock()` returns `true`, otherwise `owns_lock()` returns `false`.

Throws: Any exceptions thrown by the call to `m.try_lock_until(abs_time)`.

#### `template <class Rep, class Period> unique_lock(Lockable & m,const chrono::duration<Rep, Period>& abs_time)`

Effects: Stores a reference to `m`. Invokes `m.try_lock_for(rel_time)`, and takes ownership of the lock state if the call returns `true`.

Postcondition: `mutex()` returns `&m`. If the call to `try_lock_for` returned `true`, then `owns_lock()` returns `true`, otherwise `owns_lock()` returns `false`.

Throws: Any exceptions thrown by the call to `m.try_lock_for(rel_time)`.

#### `~unique_lock()`

Effects: Invokes `mutex()->` `unlock()` if `owns_lock()` returns `true`.

Throws: Nothing.

#### `bool owns_lock() const`

Returns: `true` if the `*this` owns the lock on the `Lockable` object associated with `*this`.

Throws: Nothing.

### `Lockable* mutex() const`

Returns: A pointer to the `Lockable` object associated with `*this`, or `NULL` if there is no such object.

Throws: Nothing.

### `explicit operator bool() const`

Returns: `owns_lock()()`.

Throws: Nothing.

### `Lockable* release()`

Effects: The association between `*this` and the `Lockable` object is removed, without affecting the lock state of the `Lockable` object. If `owns_lock()` would have returned `true`, it is the responsibility of the calling code to ensure that the `Lockable` is correctly unlocked.

Returns: A pointer to the `Lockable` object associated with `*this` at the point of the call, or `NULL` if there is no such object.

Throws: Nothing.

Postcondition: `*this` is no longer associated with any `Lockable` object. `mutex()` returns `NULL` and `owns_lock()` returns `false`.

# Class template `shared_lock` - EXTENSION

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/lock_types.hpp>

template<typename Lockable>
class shared_lock
{
public:
    typedef Lockable mutex_type;

    // Shared locking
    shared_lock();
    explicit shared_lock(Lockable& m_);
    shared_lock(Lockable& m_,adopt_lock_t);
    shared_lock(Lockable& m_,defer_lock_t);
    shared_lock(Lockable& m_,try_to_lock_t);
    template <class Clock, class Duration>
    shared_lock(Mutex& mtx, const chrono::time_point<Clock, Duration>& t);
    template <class Rep, class Period>
    shared_lock(Mutex& mtx, const chrono::duration<Rep, Period>& d);
    ~shared_lock();

    shared_lock(shared_lock const&) = delete;
    shared_lock& operator=(shared_lock const&) = delete;

    shared_lock(shared_lock<Lockable> && other);
    shared_lock& operator=(shared_lock<Lockable> && other);

    void lock();
    bool try_lock();
    template <class Rep, class Period>
    bool try_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_until(const chrono::time_point<Clock, Duration>& abs_time);
    void unlock();

    // Conversion from upgrade locking
    explicit shared_lock(upgrade_lock<Lockable> && other);

    // Conversion from exclusive locking
    explicit shared_lock(unique_lock<Lockable> && other);

    // Setters
    void swap(shared_lock& other);
    mutex_type* release() noexcept;

    // Getters
    explicit operator bool() const;
    bool owns_lock() const;
    mutex_type mutex() const;

#if defined BOOST_THREAD_USE_DATE_TIME || defined BOOST_THREAD_DONT_USE_CHRONO
    shared_lock(Lockable& m_,system_time const& target_time);
    bool timed_lock(boost::system_time const& target_time);
#endif
};
```

Like `boost::unique_lock`, `boost::shared_lock` models the `Lockable` concept, but rather than acquiring unique ownership of the supplied `Lockable` object, locking an instance of `boost::shared_lock` acquires shared ownership.

Like `boost::unique_lock`, not only does it provide for RAII-style locking, it also allows for deferring acquiring the lock until the `lock()` member function is called explicitly, or trying to acquire the lock in a non-blocking fashion, or with a timeout. Consequently, `unlock()` is only called in the destructor if the lock object has locked the `Lockable` object, or otherwise adopted a lock on the `Lockable` object.

An instance of `boost::shared_lock` is said to *own* the lock state of a `Lockable` `m` if `mutex()` returns a pointer to `m` and `owns_lock()` returns `true`. If an object that *owns* the lock state of a `Lockable` object is destroyed, then the destructor will invoke `mutex()->unlock_shared()`.

The member functions of `boost::shared_lock` are not thread-safe. In particular, `boost::shared_lock` is intended to model the shared ownership of a `Lockable` object by a particular thread, and the member functions that release ownership of the lock state (including the destructor) must be called by the same thread that acquired ownership of the lock state.

### `shared_lock()`

Effects: Creates a lock object with no associated mutex.

Postcondition: `owns_lock()` returns `false`. `mutex()` returns `NULL`.

Throws: Nothing.

### `shared_lock(Lockable & m)`

Effects: Stores a reference to `m`. Invokes `m.lock_shared()`.

Postcondition: `owns_lock()` returns `true`. `mutex()` returns `&m`.

Throws: Any exception thrown by the call to `m.lock_shared()`.

### `shared_lock(Lockable & m,boost::adopt_lock_t)`

Precondition: The current thread owns an exclusive lock on `m`.

Effects: Stores a reference to `m`. Takes ownership of the lock state of `m`.

Postcondition: `owns_lock()` returns `true`. `mutex()` returns `&m`.

Throws: Nothing.

### `shared_lock(Lockable & m,boost::defer_lock_t)`

Effects: Stores a reference to `m`.

Postcondition: `owns_lock()` returns `false`. `mutex()` returns `&m`.

Throws: Nothing.

### `shared_lock(Lockable & m,boost::try_to_lock_t)`

Effects: Stores a reference to `m`. Invokes `m.try_lock_shared()`, and takes ownership of the lock state if the call returns `true`.

Postcondition: `mutex()` returns `&m`. If the call to `try_lock_shared()` returned `true`, then `owns_lock()` returns `true`, otherwise `owns_lock()` returns `false`.

Throws: Nothing.

#### `shared_lock(Lockable & m,boost::system_time const& abs_time)`

Effects: Stores a reference to `m`. Invokes `m.timed_lock(abs_time)`, and takes ownership of the lock state if the call returns `true`.

Postcondition: `mutex()` returns `&m`. If the call to `timed_lock_shared()` returned `true`, then `owns_lock()` returns `true`, otherwise `owns_lock()` returns `false`.

Throws: Any exceptions thrown by the call to `m.timed_lock(abs_time)`.

#### `~shared_lock()`

Effects: Invokes `mutex()`-> `unlock_shared()` if `owns_lock()` returns `true`.

Throws: Nothing.

#### `bool owns_lock() const`

Returns: `true` if the `*this` owns the lock on the `Lockable` object associated with `*this`.

Throws: Nothing.

#### `Lockable* mutex() const`

Returns: A pointer to the `Lockable` object associated with `*this`, or `NULL` if there is no such object.

Throws: Nothing.

#### `explicit operator bool() const`

Returns: `owns_lock()`.

Throws: Nothing.

#### `Lockable* release()`

Effects: The association between `*this` and the `Lockable` object is removed, without affecting the lock state of the `Lockable` object. If `owns_lock()` would have returned `true`, it is the responsibility of the calling code to ensure that the `Lockable` is correctly unlocked.

Returns: A pointer to the `Lockable` object associated with `*this` at the point of the call, or `NULL` if there is no such object.

Throws: Nothing.

Postcondition: `*this` is no longer associated with any `Lockable` object. `mutex()` returns `NULL` and `owns_lock()` returns `false`.

# Class template `upgrade_lock` - EXTENSION

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/lock_types.hpp>

template<typename Lockable>
class upgrade_lock
{
public:
    typedef Lockable mutex_type;

    // Upgrade locking

    upgrade_lock();
    explicit upgrade_lock(mutex_type& m_);
    upgrade_lock(mutex_type& m, defer_lock_t) noexcept;
    upgrade_lock(mutex_type& m, try_to_lock_t);
    upgrade_lock(mutex_type& m, adopt_lock_t);
    template <class Clock, class Duration>
    upgrade_lock(mutex_type& m,
                 const chrono::time_point<Clock, Duration>& abs_time);
    template <class Rep, class Period>
    upgrade_lock(mutex_type& m,
                 const chrono::duration<Rep, Period>& rel_time);
    ~upgrade_lock();

    upgrade_lock(const upgrade_lock& other) = delete;
    upgrade_lock& operator=(const upgrade_lock<Lockable> & other) = delete;

    upgrade_lock(upgrade_lock<Lockable> && other);
    upgrade_lock& operator=(upgrade_lock<Lockable> && other);

    void lock();
    bool try_lock();
    template <class Rep, class Period>
    bool try_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_until(const chrono::time_point<Clock, Duration>& abs_time);
    void unlock();

#ifdef BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION
   // Conversion from shared locking
    upgrade_lock(shared_lock<mutex_type>&& sl, try_to_lock_t);
    template <class Clock, class Duration>
    upgrade_lock(shared_lock<mutex_type>&& sl,
                   const chrono::time_point<Clock, Duration>& abs_time);
    template <class Rep, class Period>
    upgrade_lock(shared_lock<mutex_type>&& sl,
                   const chrono::duration<Rep, Period>& rel_time);
#endif

    // Conversion from exclusive locking
    explicit upgrade_lock(unique_lock<Lockable> && other);

    // Setters
    void swap(upgrade_lock& other);
    mutex_type* release() noexcept;

    // Getters
    explicit operator bool() const;
    bool owns_lock() const;
    mutex_type mutex() const;
};
```

Like boost::unique_lock, boost::upgrade_lock models the Lockable concept, but rather than acquiring unique ownership of the supplied Lockable object, locking an instance of boost::upgrade_lock acquires upgrade ownership.

Like boost::unique_lock, not only does it provide for RAII-style locking, it also allows for deferring acquiring the lock until the lock() member function is called explicitly, or trying to acquire the lock in a non-blocking fashion, or with a timeout. Consequently, unlock() is only called in the destructor if the lock object has locked the Lockable object, or otherwise adopted a lock on the Lockable object.

An instance of boost::upgrade_lock is said to *own* the lock state of a Lockable m if mutex() returns a pointer to m and owns_lock() returns true. If an object that *owns* the lock state of a Lockable object is destroyed, then the destructor will invoke mutex()->unlock_upgrade().

The member functions of boost::upgrade_lock are not thread-safe. In particular, boost::upgrade_lock is intended to model the upgrade ownership of a UpgradeLockable object by a particular thread, and the member functions that release ownership of the lock state (including the destructor) must be called by the same thread that acquired ownership of the lock state.

## Class template upgrade_to_unique_lock

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/lock_types.hpp>

template <class Lockable>
class upgrade_to_unique_lock
{
public:
    typedef Lockable mutex_type;
    explicit upgrade_to_unique_lock(upgrade_lock<Lockable>& m_);
    ~upgrade_to_unique_lock();

    upgrade_to_unique_lock(upgrade_to_unique_lock const& other) = delete;
    upgrade_to_unique_lock& operator=(upgrade_to_unique_lock<Lockable> const& other) = delete;

    upgrade_to_unique_lock(upgrade_to_unique_lock<Lockable> && other);
    upgrade_to_unique_lock& operator=(upgrade_to_unique_lock<Lockable> && other);

    void swap(upgrade_to_unique_lock& other);

    explicit operator bool() const;
    bool owns_lock() const;
};
```

boost::upgrade_to_unique_lock allows for a temporary upgrade of an boost::upgrade_lock to exclusive ownership. When constructed with a reference to an instance of boost::upgrade_lock, if that instance has upgrade ownership on some Lockable object, that ownership is upgraded to exclusive ownership. When the boost::upgrade_to_unique_lock instance is destroyed, the ownership of the Lockable is downgraded back to *upgrade ownership*.

## Mutex-specific class `scoped_try_lock`

```
class MutexType::scoped_try_lock
{
private:
    MutexType::scoped_try_lock(MutexType::scoped_try_lock<MutexType>& other);
    MutexType::scoped_try_lock& operator=(MutexType::scoped_try_lock<MutexType>& other);
public:
    MutexType::scoped_try_lock();
    explicit MutexType::scoped_try_lock(MutexType& m);
    MutexType::scoped_try_lock(MutexType& m_,adopt_lock_t);
    MutexType::scoped_try_lock(MutexType& m_,defer_lock_t);
    MutexType::scoped_try_lock(MutexType& m_,try_to_lock_t);

    MutexType::scoped_try_lock(MutexType::scoped_try_lock<MutexType>&& other);
    MutexType::scoped_try_lock& operator=(MutexType::scoped_try_lock<MutexType>&& other);

    void swap(MutexType::scoped_try_lock&& other);

    void lock();
    bool try_lock();
    void unlock();

    MutexType* mutex() const;
    MutexType* release();

    explicit operator bool() const;
    bool owns_lock() const;
};
```

The member typedef `scoped_try_lock` is provided for each distinct `MutexType` as a typedef to a class with the preceding definition. The semantics of each constructor and member function are identical to those of `boost::unique_lock<MutexType>` for the same `MutexType`, except that the constructor that takes a single reference to a mutex will call `m.try_lock()` rather than `m.lock()`.

# Other Lock Types - EXTENSION

## Strict Locks

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/strict_lock.hpp>

namespace boost
{

  template<typename Lockable>
  class strict_lock;
  template <typename Lock>
  class nested_strict_lock;
  template <typename Lockable>
  struct is_strict_lock_sur_parolle<strict_lock<Lockable> >;
  template <typename Lock>
  struct is_strict_lock_sur_parolle<nested_strict_lock<Lock> >;

#if ! defined BOOST_THREAD_NO_MAKE_STRICT_LOCK
  template <typename Lockable>
  strict_lock<Lockable> make_strict_lock(Lockable& mtx);
#endif
#if ! defined BOOST_THREAD_NO_MAKE_NESTED_STRICT_LOCK
  template <typename Lock>
  nested_strict_lock<Lock> make_nested_strict_lock(Lock& lk);
#endif

}
```

### Class template `strict_lock`

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/strict_lock.hpp>

template<typename BasicLockable>
class strict_lock
{
public:
    typedef BasicLockable mutex_type;
    explicit strict_lock(mutex_type& m_);
    ~strict_lock();

    bool owns_lock(mutex_type const* l) const noexcept;
};
```

`strict_lock` is a model of `StrictLock`.

`strict_lock` is the simplest `StrictLock`: on construction it acquires ownership of the implementation of the `BasicLockable` concept supplied as the constructor parameter. On destruction, the ownership is released. This provides simple RAII-style locking of a `BasicLockable` object, to facilitate exception-safe locking and unlocking.

#### See also `boost::lock_guard`

#### `strict_lock(Lockable & m)`

Effects: Stores a reference to `m`. Invokes `m.lock()`.

Throws: Any exception thrown by the call to `m.lock()`.

#### `~strict_lock()`

Effects: Invokes `m.unlock()` on the `Lockable` object passed to the constructor.

Throws: Nothing.

### Class template `nested_strict_lock`

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/strict_lock.hpp>

template<typename Lock>
class nested_strict_lock
{
public:
    typedef BasicLockable mutex_type;
    explicit nested_strict_lock(Lock& lk),
    ~nested_strict_lock() noexcept;

    bool owns_lock(mutex_type const* l) const noexcept;
};
```

`nested_strict_lock` is a model of `StrictLock`.

A nested strict lock is a scoped lock guard ensuring a mutex is locked on its scope, by taking ownership of an nesting lock, locking the mutex on construction if not already locked and restoring the ownership to the nesting lock on destruction.

#### See also `strict_lock`, `boost::unique_lock`

#### `nested_strict_lock(Lock & lk)`

Requires: `lk.mutex() != null_ptr`.

Effects: Stores the reference to the lock parameter `lk` and takes ownership on it. If the lock doesn't owns the mutex lock it.

Postcondition: `owns_lock(lk.mutex())`.

Throws: - lock_error when BOOST_THREAD_THROW_IF_PRECONDITION_NOT_SATISFIED is defined and lk.mutex() == null_ptr

- Any exception that @c lk.lock() can throw.

#### `~nested_strict_lock() noexcept`

Effects: Restores ownership to the nesting lock.

#### `bool owns_lock(mutex_type const* l) const noexcept`

Return: Whether if this lock is locking that mutex.

### Non Member Function `make_strict_lock`

```
template <typename Lockable>
strict_lock<Lockable> make_strict_lock(Lockable& m); // EXTENSION
```

Returns: a strict_lock as if initialized with `{m}`.

Throws: Any exception thrown by the call to `m.lock()`.

### Non Member Function `make_nested_strict_lock`

```
template <typename Lock>
nested_strict_lock<Lock> make_nested_strict_lock(Lock& lk); // EXTENSION
```

Returns: a nested_strict_lock as if initialized with `{lk}`.

Throws: Any exception thrown by the call to `lk.lock()`.

## Externally Locked

```
// #include <boost/thread/externally_locked.hpp>
template <class T, typename MutexType = boost::mutex>
class externally_locked;
template <typename T, typename MutexType>
void swap(externally_locked<T, MutexType> & lhs, externally_locked<T, MutexType> & rhs);
```

### Template Class `externally_locked`

```
// #include <boost/thread/externally_locked.hpp>

template <class T, typename MutexType>
class externally_locked
{
  //BOOST_CONCEPT_ASSERT(( CopyConstructible<T> ));
  BOOST_CONCEPT_ASSERT(( BasicLockable<MutexType> ));

public:
  typedef MutexType mutex_type;

  externally_locked(mutex_type& mtx, const T& obj);
  externally_locked(mutex_type& mtx,T&& obj);
  explicit externally_locked(mutex_type& mtx);
  externally_locked(externally_locked&& rhs);

  // observers
  T& get(strict_lock<mutex_type>& lk);
  const T& get(strict_lock<mutex_type>& lk) const;

  template <class Lock>
  T& get(nested_strict_lock<Lock>& lk);
  template <class Lock>
  const T& get(nested_strict_lock<Lock>& lk) const;

  template <class Lock>
  T& get(Lock& lk);
  template <class Lock>
  T const& get(Lock& lk) const;

  mutex_type* mutex();

  // modifiers
  void lock();
  void unlock();
  bool try_lock();
  void swap(externally_locked&);
};
```

`externally_locked` is a model of `Lockable`, it cloaks an object of type `T`, and actually provides full access to that object through the get and set member functions, provided you pass a reference to a strict lock object.

Only the specificities respect to `Lockable` are described here.

#### `externally_locked(mutex_type&, const T&)`

```
externally_locked(mutex_type& mtx, const T& obj);
```

Requires: T is a model of CopyConstructible.

Effects: Constructs an externally locked object copying the cloaked type.

Throws: Any exception thrown by the call to `T(obj)`.

#### `externally_locked(mutex_type&, T&&)`

```
externally_locked(mutex_type& mtx,T&& obj);
```

Requires: T is a model of Movable.

Effects: Constructs an externally locked object by moving the cloaked type.

Throws: Any exception thrown by the call to `T(obj)`.

#### `externally_locked(mutex_type&)`

```
externally_locked(mutex_type& mtx);
```

Requires: T is a model of DefaultConstructible.

Effects: Constructs an externally locked object by default constructing the cloaked type.

Throws: Any exception thrown by the call to `T()`.

#### `externally_locked(externally_locked&)`

```
externally_locked(externally_locked&& rhs);
```

Requires: T is a model of Movable.

Effects: Moves an externally locked object by moving the the cloaked type and copying the mutex reference

Throws: Any exception thrown by the call to `T(T&&)`.

#### `get(strict_lock<mutex_type>&)`

```
T& get(strict_lock<mutex_type>& lk);
const T& get(strict_lock<mutex_type>& lk) const;
```

Requires: The `lk` parameter must be locking the associated mutex.

Returns: A reference to the cloaked object

Throws: `lock_error` if `BOOST_THREAD_THROW_IF_PRECONDITION_NOT_SATISFIED` is defined and the run-time preconditions are not satisfied .

### `get(strict_lock<nested_strict_lock<Lock>>&)`

```
template <class Lock>
T& get(nested_strict_lock<Lock>& lk);
template <class Lock>
const T& get(nested_strict_lock<Lock>& lk) const;
```

Requires: `is_same<mutex_type, typename Lock::mutex_type>` and the `lk` parameter must be locking the associated mutex.

Returns: A reference to the cloaked object

Throws: `lock_error` if `BOOST_THREAD_THROW_IF_PRECONDITION_NOT_SATISFIED` is defined and the run-time preconditions are not satisfied .

### `get(strict_lock<nested_strict_lock<Lock>>&)`

```
template <class Lock>
T& get(Lock& lk);
template <class Lock>
T const& get(Lock& lk) const;
```

Requires: `Lock` is a model of `StrictLock`, `is_same<mutex_type, typename Lock::mutex_type>` and the `lk` parameter must be locking the associated mutex.

Returns: A reference to the cloaked object

Throws: `lock_error` if `BOOST_THREAD_THROW_IF_PRECONDITION_NOT_SATISFIED` is defined and the run-time preconditions are not satisfied .

### `swap(externally_locked, externally_locked&)`

```
template <typename T, typename MutexType>
void swap(externally_locked<T, MutexType> & lhs, externally_locked<T, MutexType> & rhs)
```

## Class template `shared_lock_guard`

```
// #include <boost/thread/shared_lock_guard.hpp>
namespace boost
{
  template<typename SharedLockable>
  class shared_lock_guard
  {
  public:
      shared_lock_guard(shared_lock_guard const&) = delete;
      shared_lock_guard& operator=(shared_lock_guard const&) = delete;

      explicit shared_lock_guard(SharedLockable& m_);
      shared_lock_guard(SharedLockable& m_,boost::adopt_lock_t);

      ~shared_lock_guard();
  };
}
```

`shared_lock_guard` is very simple: on construction it acquires shared ownership of the implementation of the `SharedLockable` concept supplied as the constructor parameter. On destruction, the ownership is released. This provides simple RAII-style locking of a `SharedLockable` object, to facilitate exception-safe shared locking and unlocking. In addition, the `shared_lock_guard(SharedLockable &m, boost::adopt_lock_t)` constructor allows the `shared_lock_guard` object to take shared ownership of a lock already held by the current thread.

**`shared_lock_guard(SharedLockable & m)`**

Effects: Stores a reference to `m`. Invokes `m.lock_shared()()`.

Throws: Any exception thrown by the call to `m.lock_shared()()`.

**`shared_lock_guard(SharedLockable & m,boost::adopt_lock_t)`**

Precondition: The current thread owns a lock on `m` equivalent to one obtained by a call to `m.lock_shared()()`.

Effects: Stores a reference to `m`. Takes ownership of the lock state of `m`.

Throws: Nothing.

**`~shared_lock_guard()`**

Effects: Invokes `m.unlock_shared()()` on the `SharedLockable` object passed to the constructor.

Throws: Nothing.

## Class template `reverse_lock`

```
// #include <boost/thread/reverse_lock.hpp>
namespace boost
{

  template<typename Lock>
  class reverse_lock
  {
  public:
      reverse_lock(reverse_lock const&) = delete;
      reverse_lock& operator=(reverse_lock const&) = delete;

      explicit reverse_lock(Lock& m_);
      ~reverse_lock();
  };
}
```

`reverse_lock` reverse the operations of a lock: it provide for RAII-style, that unlocks the lock at construction time and lock it at destruction time. In addition, it transfer ownership temporarily, so that the mutex can not be locked using the Lock.

An instance of `reverse_lock` doesn't *own* the lock never.

**`reverse_lock(Lock & m)`**

Effects: Stores a reference to `m`. Invokes `m.unlock()` if `m` owns his lock and then stores the mutex by calling `m.release()`.

Postcondition: `!m. owns_lock()() && m.mutex()==0`.

Throws: Any exception thrown by the call to `m.unlock()`.

**`~reverse_lock()`**

Effects: Let be mtx the stored mutex*. If not 0 Invokes `mtx->lock()` and gives again the `mtx` to the `Lock` using the `adopt_lock_t` overload.

Throws: Any exception thrown by `mtx->lock()`.

Remarks: Note that if `mtx->lock()` throws an exception while unwinding the program will terminate, so don't use reverse_lock if an exception can be thrown.

# Lock functions

## Non-member function `lock(Lockable1,Lockable2,...)`

```
// #include <boost/thread/locks.hpp>
// #include <boost/thread/lock_algorithms.hpp>
namespace boost
{

  template<typename Lockable1,typename Lockable2>
  void lock(Lockable1& l1,Lockable2& l2);

  template<typename Lockable1,typename Lockable2,typename Lockable3>
  void lock(Lockable1& l1,Lockable2& l2,Lockable3& l3);

  template<typename Lockable1,typename Lockable2,typename Lockable3,typename Lockable4>
  void lock(Lockable1& l1,Lockable2& l2,Lockable3& l3,Lockable4& l4);

  template<typename Lockable1,typename Lockable2,typename Lockable3,typename Lockable4,type↵
name Lockable5>
  void lock(Lockable1& l1,Lockable2& l2,Lockable3& l3,Lockable4& l4,Lockable5& l5);

}
```

Effects: Locks the `Lockable` objects supplied as arguments in an unspecified and indeterminate order in a way that avoids deadlock. It is safe to call this function concurrently from multiple threads with the same mutexes (or other lockable objects) in different orders without risk of deadlock. If any of the `lock()` or `try_lock()` operations on the supplied `Lockable` objects throws an exception any locks acquired by the function will be released before the function exits.

Throws: Any exceptions thrown by calling `lock()` or `try_lock()` on the supplied `Lockable` objects.

Postcondition: All the supplied `Lockable` objects are locked by the calling thread.

## Non-member function `lock(begin,end)` // EXTENSION

```
template<typename ForwardIterator>
void lock(ForwardIterator begin,ForwardIterator end);
```

Preconditions: The `value_type` of `ForwardIterator` must implement the `Lockable` concept

Effects: Locks all the `Lockable` objects in the supplied range in an unspecified and indeterminate order in a way that avoids deadlock. It is safe to call this function concurrently from multiple threads with the same mutexes (or other lockable objects) in different orders without risk of deadlock. If any of the `lock()` or `try_lock()` operations on the `Lockable` objects in the supplied range throws an exception any locks acquired by the function will be released before the function exits.

Throws: Any exceptions thrown by calling `lock()` or `try_lock()` on the supplied `Lockable` objects.

Postcondition: All the `Lockable` objects in the supplied range are locked by the calling thread.

## Non-member function `try_lock(Lockable1,Lockable2,...)`

```
template<typename Lockable1,typename Lockable2>
int try_lock(Lockable1& l1,Lockable2& l2);

template<typename Lockable1,typename Lockable2,typename Lockable3>
int try_lock(Lockable1& l1,Lockable2& l2,Lockable3& l3);

template<typename Lockable1,typename Lockable2,typename Lockable3,typename Lockable4>
int try_lock(Lockable1& l1,Lockable2& l2,Lockable3& l3,Lockable4& l4);

template<typename Lockable1,typename Lockable2,typename Lockable3,typename Lockable4,typename Lock↵
able5>
int try_lock(Lockable1& l1,Lockable2& l2,Lockable3& l3,Lockable4& l4,Lockable5& l5);
```

Effects: Calls `try_lock()` on each of the `Lockable` objects supplied as arguments. If any of the calls to `try_lock()` returns `false` then all locks acquired are released and the zero-based index of the failed lock is returned.

If any of the `try_lock()` operations on the supplied `Lockable` objects throws an exception any locks acquired by the function will be released before the function exits.

Returns: `-1` if all the supplied `Lockable` objects are now locked by the calling thread, the zero-based index of the object which could not be locked otherwise.

Throws: Any exceptions thrown by calling `try_lock()` on the supplied `Lockable` objects.

Postcondition: If the function returns `-1`, all the supplied `Lockable` objects are locked by the calling thread. Otherwise any locks acquired by this function will have been released.

## Non-member function `try_lock(begin,end)` // EXTENSION

```
template<typename ForwardIterator>
ForwardIterator try_lock(ForwardIterator begin,ForwardIterator end);
```

Preconditions: The `value_type` of `ForwardIterator` must implement the `Lockable` concept

Effects: Calls `try_lock()` on each of the `Lockable` objects in the supplied range. If any of the calls to `try_lock()` returns `false` then all locks acquired are released and an iterator referencing the failed lock is returned.

If any of the `try_lock()` operations on the supplied `Lockable` objects throws an exception any locks acquired by the function will be released before the function exits.

Returns: `end` if all the supplied `Lockable` objects are now locked by the calling thread, an iterator referencing the object which could not be locked otherwise.

Throws: Any exceptions thrown by calling `try_lock()` on the supplied `Lockable` objects.

Postcondition: If the function returns `end` then all the `Lockable` objects in the supplied range are locked by the calling thread, otherwise all locks acquired by the function have been released.

# Lock Factories - EXTENSION

```
namespace boost
{

  template <typename Lockable>
  unique_lock<Lockable> make_unique_lock(Lockable& mtx); // EXTENSION

  template <typename Lockable>
  unique_lock<Lockable> make_unique_lock(Lockable& mtx, adopt_lock_t); // EXTENSION
  template <typename Lockable>
  unique_lock<Lockable> make_unique_lock(Lockable& mtx, defer_lock_t); // EXTENSION
  template <typename Lockable>
  unique_lock<Lockable> make_unique_lock(Lockable& mtx, try_to_lock_t); // EXTENSION

#if ! defined(BOOST_THREAD_NO_MAKE_UNIQUE_LOCKS)
  template <typename ...Lockable>
  std::tuple<unique_lock<Lockable> ...> make_unique_locks(Lockable& ...mtx); // EXTENSION
#endif
}
```

## Non Member Function `make_unique_lock(Lockable&)`

```
template <typename Lockable>
unique_lock<Lockable> make_unique_lock(Lockable& mtx); // EXTENSION
```

Returns: a `boost::unique_lock` as if initialized with `unique_lock<Lockable>(mtx)`.

Throws: Any exception thrown by the call to `boost::unique_lock<Lockable>(mtx)`.

## Non Member Function `make_unique_lock(Lockable&,tag)`

```
template <typename Lockable>
unique_lock<Lockable> make_unique_lock(Lockable& mtx, adopt_lock_t tag); // EXTENSION

template <typename Lockable>
unique_lock<Lockable> make_unique_lock(Lockable& mtx, defer_lock_t tag); // EXTENSION

template <typename Lockable>
unique_lock<Lockable> make_unique_lock(Lockable& mtx, try_to_lock_t tag); // EXTENSION
```

Returns: a `boost::unique_lock` as if initialized with `unique_lock<Lockable>(mtx, tag)`.

Throws: Any exception thrown by the call to `boost::unique_lock<Lockable>(mtx, tag)`.

## Non Member Function `make_unique_locks(Lockable& ...)`

```
template <typename ...Lockable>
std::tuple<unique_lock<Lockable> ...> make_unique_locks(Lockable& ...mtx); // EXTENSION
```

Effect: Locks all the mutexes.

Returns: a std::tuple of unique `boost::unique_lock` owning each one of the mutex.

Throws: Any exception thrown by `boost::lock(mtx...)`.

# Mutex Types

## Class `mutex`

```
#include <boost/thread/mutex.hpp>

class mutex:
    boost::noncopyable
{
public:
    mutex();
    ~mutex();

    void lock();
    bool try_lock();
    void unlock();

    typedef platform-specific-type native_handle_type;
    native_handle_type native_handle();

    typedef unique_lock<mutex> scoped_lock;
    typedef unspecified-type scoped_try_lock;
};
```

`boost::mutex` implements the `Lockable` concept to provide an exclusive-ownership mutex. At most one thread can own the lock on a given instance of `boost::mutex` at any time. Multiple concurrent calls to `lock()`, `try_lock()` and `unlock()` shall be permitted.

### Member function `native_handle()`

```
typedef platform-specific-type native_handle_type;
native_handle_type native_handle();
```

Effects: Returns an instance of `native_handle_type` that can be used with platform-specific APIs to manipulate the underlying implementation. If no such instance exists, `native_handle()` and `native_handle_type` are not present.

Throws: Nothing.

## Typedef `try_mutex`

```
#include <boost/thread/mutex.hpp>

typedef mutex try_mutex;
```

`boost::try_mutex` is a `typedef` to `boost::mutex`, provided for backwards compatibility with previous releases of boost.

## Class `timed_mutex`

```
#include <boost/thread/mutex.hpp>

class timed_mutex:
    boost::noncopyable
{
public:
    timed_mutex();
    ~timed_mutex();

    void lock();
    void unlock();
    bool try_lock();

    template <class Rep, class Period>
    bool try_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_until(const chrono::time_point<Clock, Duration>& t);

    typedef platform-specific-type native_handle_type;
    native_handle_type native_handle();

    typedef unique_lock<timed_mutex> scoped_timed_lock;
    typedef unspecified-type scoped_try_lock;
    typedef scoped_timed_lock scoped_lock;

#if defined BOOST_THREAD_PROVIDES_DATE_TIME || defined BOOST_THREAD_DONT_USE_CHRONO
    bool timed_lock(system_time const & abs_time);
    template<typename TimeDuration>
    bool timed_lock(TimeDuration const & relative_time);
#endif

};
```

`boost::timed_mutex` implements the `TimedLockable` concept to provide an exclusive-ownership mutex. At most one thread can own the lock on a given instance of `boost::timed_mutex` at any time. Multiple concurrent calls to `lock()`, `try_lock()`, `timed_lock()`, `timed_lock()` and `unlock()` shall be permitted.

### Member function `native_handle()`

```
typedef platform-specific-type native_handle_type;
native_handle_type native_handle();
```

Effects: Returns an instance of `native_handle_type` that can be used with platform-specific APIs to manipulate the underlying implementation. If no such instance exists, `native_handle()` and `native_handle_type` are not present.

Throws: Nothing.

## Class recursive_mutex

```
#include <boost/thread/recursive_mutex.hpp>

class recursive_mutex:
    boost::noncopyable
{
public:
    recursive_mutex();
    ~recursive_mutex();

    void lock();
    bool try_lock() noexcept;
    void unlock();

    typedef platform-specific-type native_handle_type;
    native_handle_type native_handle();

    typedef unique_lock<recursive_mutex> scoped_lock;
    typedef unspecified-type scoped_try_lock;
};
```

`boost::recursive_mutex` implements the `Lockable` concept to provide an exclusive-ownership recursive mutex. At most one thread can own the lock on a given instance of `boost::recursive_mutex` at any time. Multiple concurrent calls to `lock()`, `try_lock()` and `unlock()` shall be permitted. A thread that already has exclusive ownership of a given `boost::recursive_mutex` instance can call `lock()` or `try_lock()` to acquire an additional level of ownership of the mutex. `unlock()` must be called once for each level of ownership acquired by a single thread before ownership can be acquired by another thread.

### Member function native_handle()

```
typedef platform-specific-type native_handle_type;
native_handle_type native_handle();
```

Effects: Returns an instance of `native_handle_type` that can be used with platform-specific APIs to manipulate the underlying implementation. If no such instance exists, `native_handle()` and `native_handle_type` are not present.

Throws: Nothing.

## Typedef recursive_try_mutex

```
#include <boost/thread/recursive_mutex.hpp>

typedef recursive_mutex recursive_try_mutex;
```

`boost::recursive_try_mutex` is a `typedef` to `boost::recursive_mutex`, provided for backwards compatibility with previous releases of boost.

## Class `recursive_timed_mutex`

```
#include <boost/thread/recursive_mutex.hpp>

class recursive_timed_mutex:
    boost::noncopyable
{
public:
    recursive_timed_mutex();
    ~recursive_timed_mutex();

    void lock();
    bool try_lock() noexcept;
    void unlock();


    template <class Rep, class Period>
    bool try_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_until(const chrono::time_point<Clock, Duration>& t);

    typedef platform-specific-type native_handle_type;
    native_handle_type native_handle();

    typedef unique_lock<recursive_timed_mutex> scoped_lock;
    typedef unspecified-type scoped_try_lock;
    typedef scoped_lock scoped_timed_lock;

#if defined BOOST_THREAD_PROVIDES_DATE_TIME || defined BOOST_THREAD_DONT_USE_CHRONO
    bool timed_lock(system_time const & abs_time);
    template<typename TimeDuration>
    bool timed_lock(TimeDuration const & relative_time);
#endif

};
```

`boost::recursive_timed_mutex` implements the `TimedLockable` concept to provide an exclusive-ownership recursive mutex. At most one thread can own the lock on a given instance of `boost::recursive_timed_mutex` at any time. Multiple concurrent calls to `lock()`, `try_lock()`, `timed_lock()`, `timed_lock()` and `unlock()` shall be permitted. A thread that already has exclusive ownership of a given `boost::recursive_timed_mutex` instance can call `lock()`, `timed_lock()`, `timed_lock()` or `try_lock()` to acquire an additional level of ownership of the mutex. `unlock()` must be called once for each level of ownership acquired by a single thread before ownership can be acquired by another thread.

### Member function `native_handle()`

```
typedef platform-specific-type native_handle_type;
native_handle_type native_handle();
```

Effects: Returns an instance of `native_handle_type` that can be used with platform-specific APIs to manipulate the underlying implementation. If no such instance exists, `native_handle()` and `native_handle_type` are not present.

Throws: Nothing.

# Class `shared_mutex` -- EXTENSION

```
#include <boost/thread/shared_mutex.hpp>

class shared_mutex
{
public:
    shared_mutex(shared_mutex const&) = delete;
    shared_mutex& operator=(shared_mutex const&) = delete;

    shared_mutex();
    ~shared_mutex();

    void lock_shared();
    bool try_lock_shared();
    template <class Rep, class Period>
    bool try_lock_shared_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_shared_until(const chrono::time_point<Clock, Duration>& abs_time);
    void unlock_shared();

    void lock();
    bool try_lock();
    template <class Rep, class Period>
    bool try_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_until(const chrono::time_point<Clock, Duration>& abs_time);
    void unlock();

#if defined BOOST_THREAD_PROVIDES_DEPRECATED_FEATURES_SINCE_V3_0_0
    // use upgrade_mutex instead.
    void lock_upgrade();
    void unlock_upgrade();

    void unlock_upgrade_and_lock();
    void unlock_and_lock_upgrade();
    void unlock_and_lock_shared();
    void unlock_upgrade_and_lock_shared();
#endif

#if defined BOOST_THREAD_USES_DATETIME
    bool timed_lock_shared(system_time const& timeout);
    bool timed_lock(system_time const& timeout);
#endif

};
```

The class `boost::shared_mutex` provides an implementation of a multiple-reader / single-writer mutex. It implements the `SharedLockable` concept.

Multiple concurrent calls to `lock()`, `try_lock()`, `try_lock_for()`, `try_lock_until()`, `timed_lock()`, `lock_shared()`, `try_lock_shared_for()`, `try_lock_shared_until()`, `try_lock_shared()` and `timed_lock_shared()` are permitted.

Note the the lack of reader-writer priority policies in shared_mutex. This is due to an algorithm credited to Alexander Terekhov which lets the OS decide which thread is the next to get the lock without caring whether a unique lock or shared lock is being sought. This results in a complete lack of reader or writer starvation. It is simply fair.

## Class `upgrade_mutex` -- EXTENSION

```
#include <boost/thread/shared_mutex.hpp>

class upgrade_mutex
{
public:
    upgrade_mutex(upgrade_mutex const&) = delete;
    upgrade_mutex& operator=(upgrade_mutex const&) = delete;

    upgrade_mutex();
    ~upgrade_mutex();

    void lock_shared();
    bool try_lock_shared();
    template <class Rep, class Period>
    bool try_lock_shared_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_shared_until(const chrono::time_point<Clock, Duration>& abs_time);
    void unlock_shared();

    void lock();
    bool try_lock();
    template <class Rep, class Period>
    bool try_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_until(const chrono::time_point<Clock, Duration>& abs_time);
    void unlock();

    void lock_upgrade();
    template <class Rep, class Period>
    bool try_lock_upgrade_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_upgrade_until(const chrono::time_point<Clock, Duration>& abs_time);
    void unlock_upgrade();

    // Shared <-> Exclusive

#ifdef BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSIONS
    bool try_unlock_shared_and_lock();
    template <class Rep, class Period>
    bool try_unlock_shared_and_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_unlock_shared_and_lock_until(const chrono::time_point<Clock, Duration>& abs_time);
#endif
    void unlock_and_lock_shared();

    // Shared <-> Upgrade

#ifdef BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSIONS
    bool try_unlock_shared_and_lock_upgrade();
    template <class Rep, class Period>
    bool try_unlock_shared_and_lock_upgrade_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_unlock_shared_and_lock_upgrade_until(const chrono::time_point<Clock, Dura↵
tion>& abs_time);
#endif
    void unlock_upgrade_and_lock_shared();

    // Upgrade <-> Exclusive

    void unlock_upgrade_and_lock();
#if    defined(BOOST_THREAD_PLATFORM_PTHREAD)
```

```
    || defined(BOOST_THREAD_PROVIDES_GENERIC_SHARED_MUTEX_ON_WIN)
    bool try_unlock_upgrade_and_lock();
    template <class Rep, class Period>
    bool try_unlock_upgrade_and_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
   bool try_unlock_upgrade_and_lock_until(const chrono::time_point<Clock, Duration>& abs_time);
#endif
    void unlock_and_lock_upgrade();
};
```

The class `boost::upgrade_mutex` provides an implementation of a multiple-reader / single-writer mutex. It implements the `UpgradeLockable` concept.

Multiple concurrent calls to `lock()`, `try_lock()`, `try_lock_for()`, `try_lock_until()`, `timed_lock()`, `lock_shared()`, `try_lock_shared_for()`, `try_lock_shared_until()`, `try_lock_shared()` and `timed_lock_shared()` are permitted.

## Class `null_mutex` -- EXTENSION

```
#include <boost/thread/null_mutex.hpp>

class null_mutex
{
public:
    null_mutex(null_mutex const&) = delete;
    null_mutex& operator=(null_mutex const&) = delete;

    null_mutex();
    ~null_mutex();

    void lock_shared();
    bool try_lock_shared();
 #ifdef BOOST_THREAD_USES_CHRONO
    template <class Rep, class Period>
    bool try_lock_shared_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_shared_until(const chrono::time_point<Clock, Duration>& abs_time);
 #endif
    void unlock_shared();

    void lock();
    bool try_lock();
 #ifdef BOOST_THREAD_USES_CHRONO
    template <class Rep, class Period>
    bool try_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_until(const chrono::time_point<Clock, Duration>& abs_time);
 #endif
    void unlock();

    void lock_upgrade();
 #ifdef BOOST_THREAD_USES_CHRONO
    template <class Rep, class Period>
    bool try_lock_upgrade_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_lock_upgrade_until(const chrono::time_point<Clock, Duration>& abs_time);
 #endif
    void unlock_upgrade();

    // Shared <-> Exclusive

    bool try_unlock_shared_and_lock();
```

```
 #ifdef BOOST_THREAD_USES_CHRONO
    template <class Rep, class Period>
    bool try_unlock_shared_and_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_unlock_shared_and_lock_until(const chrono::time_point<Clock, Duration>& abs_time);
 #endif
    void unlock_and_lock_shared();

    // Shared <-> Upgrade

    bool try_unlock_shared_and_lock_upgrade();
 #ifdef BOOST_THREAD_USES_CHRONO
    template <class Rep, class Period>
    bool try_unlock_shared_and_lock_upgrade_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_unlock_shared_and_lock_upgrade_until(const chrono::time_point<Clock, Dura↵
tion>& abs_time);
 #endif
    void unlock_upgrade_and_lock_shared();

    // Upgrade <-> Exclusive

    void unlock_upgrade_and_lock();
    bool try_unlock_upgrade_and_lock();
 #ifdef BOOST_THREAD_USES_CHRONO
    template <class Rep, class Period>
    bool try_unlock_upgrade_and_lock_for(const chrono::duration<Rep, Period>& rel_time);
    template <class Clock, class Duration>
    bool try_unlock_upgrade_and_lock_until(const chrono::time_point<Clock, Duration>& abs_time);
 #endif
    void unlock_and_lock_upgrade();
};
```

The class `boost::null_mutex` provides a no-op implementation of a multiple-reader / single-writer mutex. It is a model of the `UpgradeLockable` concept.

# Condition Variables

## Synopsis

```
namespace boost
{
  enum class cv_status;
  {
    no_timeout,
    timeout
  };
  class condition_variable;
  class condition_variable_any;
  void notify_all_at_thread_exit(condition_variable& cond, unique_lock<mutex> lk);
}
```

The classes `condition_variable` and `condition_variable_any` provide a mechanism for one thread to wait for notification from another thread that a particular condition has become true. The general usage pattern is that one thread locks a mutex and then calls `wait` on an instance of `condition_variable` or `condition_variable_any`. When the thread is woken from the wait, then it checks to see if the appropriate condition is now true, and continues if so. If the condition is not true, then the thread then calls `wait` again to resume waiting. In the simplest case, this condition is just a boolean variable:

```
boost::condition_variable cond;
boost::mutex mut;
bool data_ready;

void process_data();

void wait_for_data_to_process()
{
    boost::unique_lock<boost::mutex> lock(mut);
    while(!data_ready)
    {
        cond.wait(lock);
    }
    process_data();
}
```

Notice that the `lock` is passed to `wait`: `wait` will atomically add the thread to the set of threads waiting on the condition variable, and unlock the mutex. When the thread is woken, the mutex will be locked again before the call to `wait` returns. This allows other threads to acquire the mutex in order to update the shared data, and ensures that the data associated with the condition is correctly synchronized.

In the mean time, another thread sets the condition to `true`, and then calls either `notify_one` or `notify_all` on the condition variable to wake one waiting thread or all the waiting threads respectively.

```
void retrieve_data();
void prepare_data();

void prepare_data_for_processing()
{
    retrieve_data();
    prepare_data();
    {
        boost::lock_guard<boost::mutex> lock(mut);
        data_ready=true;
    }
    cond.notify_one();
}
```

Note that the same mutex is locked before the shared data is updated, but that the mutex does not have to be locked across the call to `notify_one`.

This example uses an object of type `condition_variable`, but would work just as well with an object of type `condition_variable_any`: `condition_variable_any` is more general, and will work with any kind of lock or mutex, whereas `condition_variable` requires that the lock passed to `wait` is an instance of `boost::unique_lock<boost::mutex>`. This enables `condition_variable` to make optimizations in some cases, based on the knowledge of the mutex type; `condition_variable_any` typically has a more complex implementation than `condition_variable`.

## Class condition_variable

```
//#include <boost/thread/condition_variable.hpp>

namespace boost
{
    class condition_variable
    {
    public:
        condition_variable();
        ~condition_variable();

        void notify_one() noexcept;
        void notify_all() noexcept;

        void wait(boost::unique_lock<boost::mutex>& lock);

        template<typename predicate_type>
        void wait(boost::unique_lock<boost::mutex>& lock,predicate_type predicate);

        template <class Clock, class Duration>
        typename cv_status::type
        wait_until(
            unique_lock<mutex>& lock,
            const chrono::time_point<Clock, Duration>& t);

        template <class Clock, class Duration, class Predicate>
        bool
        wait_until(
            unique_lock<mutex>& lock,
            const chrono::time_point<Clock, Duration>& t,
            Predicate pred);

        template <class Rep, class Period>
        typename cv_status::type
        wait_for(
            unique_lock<mutex>& lock,
            const chrono::duration<Rep, Period>& d);

        template <class Rep, class Period, class Predicate>
        bool
        wait_for(
            unique_lock<mutex>& lock,
            const chrono::duration<Rep, Period>& d,
            Predicate pred);

    #if defined BOOST_THREAD_USES_DATETIME
        bool timed_wait(boost::unique_lock<boost::mutex>& lock,boost::system_time const& abs_time);
        template<typename duration_type>
        bool timed_wait(boost::unique_lock<boost::mutex>& lock,duration_type const& rel_time);
        template<typename predicate_type>
        bool timed_wait(boost::unique_lock<boost::mutex>& lock,boost::sys↵
tem_time const& abs_time,predicate_type predicate);
        template<typename duration_type,typename predicate_type>
        bool timed_wait(boost::unique_lock<boost::mutex>& lock,duration_type const& rel_time,pre↵
dicate_type predicate);
        bool timed_wait(boost::unique_lock<boost::mutex>& lock,boost::xtime const& abs_time);

        template<typename predicate_type>
```

```
        bool timed_wait(boost::unique_lock<boost::mutex>& lock,boost::xtime const& abs_time,pre↵
dicate_type predicate);
    #endif

    };
}
```

### `condition_variable()`

Effects: Constructs an object of class `condition_variable`.

Throws: `boost::thread_resource_error` if an error occurs.

### `~condition_variable()`

Precondition: All threads waiting on `*this` have been notified by a call to `notify_one` or `notify_all` (though the respective calls to `wait` or `timed_wait` need not have returned).

Effects: Destroys the object.

Throws: Nothing.

### `void notify_one()`

Effects: If any threads are currently *blocked* waiting on `*this` in a call to `wait` or `timed_wait`, unblocks one of those threads.

Throws: Nothing.

### `void notify_all()`

Effects: If any threads are currently *blocked* waiting on `*this` in a call to `wait` or `timed_wait`, unblocks all of those threads.

Throws: Nothing.

### `void wait(boost::unique_lock<boost::mutex>& lock)`

Precondition: `lock` is locked by the current thread, and either no other thread is currently waiting on `*this`, or the execution of the `mutex()` member function on the `lock` objects supplied in the calls to `wait` or `timed_wait` in all the threads currently waiting on `*this` would return the same value as `lock->mutex()` for this call to `wait`.

Effects: Atomically call `lock.unlock()` and blocks the current thread. The thread will unblock when notified by a call to `this->notify_one()` or `this->notify_all()`, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking `lock.lock()` before the call to `wait` returns. The lock is also reacquired by invoking `lock.lock()` if the function exits with an exception.

Postcondition: `lock` is locked by the current thread.

Throws: `boost::thread_resource_error` if an error occurs. `boost::thread_interrupted` if the wait was interrupted by a call to `interrupt()` on the `boost::thread` object associated with the current thread of execution.

### `template<typename predicate_type> void wait(boost::unique_lock<boost::mutex>& lock, predicate_type pred)`

Effects: As-if

```
while(!pred())
{
    wait(lock);
}
```

### `bool timed_wait(boost::unique_lock<boost::mutex>& lock,boost::system_time const& abs_time)`

Precondition: `lock` is locked by the current thread, and either no other thread is currently waiting on `*this`, or the execution of the `mutex()` member function on the `lock` objects supplied in the calls to `wait` or `timed_wait` in all the threads currently waiting on `*this` would return the same value as `lock->mutex()` for this call to `wait`.

Effects: Atomically call `lock.unlock()` and blocks the current thread. The thread will unblock when notified by a call to `this->notify_one()` or `this->notify_all()`, when the time as reported by `boost::get_system_time()` would be equal to or later than the specified `abs_time`, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking `lock.lock()` before the call to `wait` returns. The lock is also reacquired by invoking `lock.lock()` if the function exits with an exception.

Returns: `false` if the call is returning because the time specified by `abs_time` was reached, `true` otherwise.

Postcondition: `lock` is locked by the current thread.

Throws: `boost::thread_resource_error` if an error occurs. `boost::thread_interrupted` if the wait was interrupted by a call to `interrupt()` on the `boost::thread` object associated with the current thread of execution.

### `template<typename duration_type> bool timed_wait(boost::unique_lock<boost::mutex>& lock,duration_type const& rel_time)`

Precondition: `lock` is locked by the current thread, and either no other thread is currently waiting on `*this`, or the execution of the `mutex()` member function on the `lock` objects supplied in the calls to `wait` or `timed_wait` in all the threads currently waiting on `*this` would return the same value as `lock->mutex()` for this call to `wait`.

Effects: Atomically call `lock.unlock()` and blocks the current thread. The thread will unblock when notified by a call to `this->notify_one()` or `this->notify_all()`, after the period of time indicated by the `rel_time` argument has elapsed, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking `lock.lock()` before the call to `wait` returns. The lock is also reacquired by invoking `lock.lock()` if the function exits with an exception.

Returns: `false` if the call is returning because the time period specified by `rel_time` has elapsed, `true` otherwise.

Postcondition: `lock` is locked by the current thread.

Throws: `boost::thread_resource_error` if an error occurs. `boost::thread_interrupted` if the wait was interrupted by a call to `interrupt()` on the `boost::thread` object associated with the current thread of execution.

> **Note**
>
> The duration overload of timed_wait is difficult to use correctly. The overload taking a predicate should be preferred in most cases.

### `template<typename predicate_type> bool timed_wait(boost::unique_lock<boost::mutex>& lock, boost::system_time const& abs_time, predicate_type pred)`

Effects: As-if

```
while(!pred())
{
    if(!timed_wait(lock,abs_time))
    {
        return pred();
    }
}
return true;
```

**template <class Clock, class Duration> cv_status wait_until(boost::unique_lock<boost::mutex>& lock, const chrono::time_point<Clock, Duration>& abs_time)**

Precondition: `lock` is locked by the current thread, and either no other thread is currently waiting on `*this`, or the execution of the `mutex()` member function on the `lock` objects supplied in the calls to `wait` or `wait_for` or `wait_until` in all the threads currently waiting on `*this` would return the same value as `lock->mutex()` for this call to `wait`.

Effects: Atomically call `lock.unlock()` and blocks the current thread. The thread will unblock when notified by a call to `this->notify_one()` or `this->notify_all()`, when the time as reported by `Clock::now()` would be equal to or later than the specified `abs_time`, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking `lock.lock()` before the call to `wait` returns. The lock is also reacquired by invoking `lock.lock()` if the function exits with an exception.

Returns: `cv_status::timeout` if the call is returning because the time specified by `abs_time` was reached, `cv_status::no_timeout` otherwise.

Postcondition: `lock` is locked by the current thread.

Throws: `boost::thread_resource_error` if an error occurs. `boost::thread_interrupted` if the wait was interrupted by a call to `interrupt()` on the `boost::thread` object associated with the current thread of execution.

**template <class Rep, class Period> cv_status wait_for(boost::unique_lock<boost::mutex>& lock, const chrono::duration<Rep, Period>& rel_time)**

Precondition: `lock` is locked by the current thread, and either no other thread is currently waiting on `*this`, or the execution of the `mutex()` member function on the `lock` objects supplied in the calls to `wait` or `wait_until` or `wait_for` in all the threads currently waiting on `*this` would return the same value as `lock->mutex()` for this call to `wait`.

Effects: Atomically call `lock.unlock()` and blocks the current thread. The thread will unblock when notified by a call to `this->notify_one()` or `this->notify_all()`, after the period of time indicated by the `rel_time` argument has elapsed, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking `lock.lock()` before the call to `wait` returns. The lock is also reacquired by invoking `lock.lock()` if the function exits with an exception.

Returns: `cv_status::timeout` if the call is returning because the time period specified by `rel_time` has elapsed, `cv_status::no_timeout` otherwise.

Postcondition: `lock` is locked by the current thread.

Throws: `boost::thread_resource_error` if an error occurs. `boost::thread_interrupted` if the wait was interrupted by a call to `interrupt()` on the `boost::thread` object associated with the current thread of execution.

### Note

The duration overload of timed_wait is difficult to use correctly. The overload taking a predicate should be preferred in most cases.

**template <class Clock, class Duration, class Predicate> bool wait_until(boost::unique_lock<boost::mutex>& lock, const chrono::time_point<Clock, Duration>& abs_time, Predicate pred)**

Effects: As-if

```
while(!pred())
{
    if(!wait_until(lock,abs_time))
    {
        return pred();
    }
}
return true;
```

**template <class Rep, class Period, class Predicate> bool wait_for(boost::unique_lock<boost::mutex>& lock, const chrono::duration<Rep, Period>& rel_time, Predicate pred)**

Effects: As-if

```
return wait_until(lock, chrono::steady_clock::now() + d, boost::move(pred));
```

## Class condition_variable_any

```
//#include <boost/thread/condition_variable.hpp>

namespace boost
{
    class condition_variable_any
    {
    public:
        condition_variable_any();
        ~condition_variable_any();

        void notify_one();
        void notify_all();

        template<typename lock_type>
        void wait(lock_type& lock);

        template<typename lock_type,typename predicate_type>
        void wait(lock_type& lock,predicate_type predicate);

        template <class lock_type, class Clock, class Duration>
        cv_status wait_until(
            lock_type& lock,
            const chrono::time_point<Clock, Duration>& t);

        template <class lock_type, class Clock, class Duration, class Predicate>
        bool wait_until(
            lock_type& lock,
            const chrono::time_point<Clock, Duration>& t,
            Predicate pred);


        template <class lock_type, class Rep, class Period>
        cv_status wait_for(
            lock_type& lock,
            const chrono::duration<Rep, Period>& d);

        template <class lock_type, class Rep, class Period, class Predicate>
        bool wait_for(
            lock_type& lock,
            const chrono::duration<Rep, Period>& d,
            Predicate pred);

    #if defined BOOST_THREAD_USES_DATETIME
        template<typename lock_type>
        bool timed_wait(lock_type& lock,boost::system_time const& abs_time);
        template<typename lock_type,typename duration_type>
        bool timed_wait(lock_type& lock,duration_type const& rel_time);
        template<typename lock_type,typename predicate_type>
       bool timed_wait(lock_type& lock,boost::system_time const& abs_time,predicate_type predic↵
ate);
        template<typename lock_type,typename duration_type,typename predicate_type>
       bool timed_wait(lock_type& lock,duration_type const& rel_time,predicate_type predicate);
        template<typename lock_type>
        bool timed_wait(lock_type>& lock,boost::xtime const& abs_time);
        template<typename lock_type,typename predicate_type>
        bool timed_wait(lock_type& lock,boost::xtime const& abs_time,predicate_type predicate);
    #endif
    };
}
```

### `condition_variable_any()`

Effects: Constructs an object of class `condition_variable_any`.

Throws: `boost::thread_resource_error` if an error occurs.

### `~condition_variable_any()`

Precondition: All threads waiting on `*this` have been notified by a call to `notify_one` or `notify_all` (though the respective calls to `wait` or `timed_wait` need not have returned).

Effects: Destroys the object.

Throws: Nothing.

### `void notify_one()`

Effects: If any threads are currently *blocked* waiting on `*this` in a call to `wait` or `timed_wait`, unblocks one of those threads.

Throws: Nothing.

### `void notify_all()`

Effects: If any threads are currently *blocked* waiting on `*this` in a call to `wait` or `timed_wait`, unblocks all of those threads.

Throws: Nothing.

### `template<typename lock_type> void wait(lock_type& lock)`

Effects: Atomically call `lock.unlock()` and blocks the current thread. The thread will unblock when notified by a call to `this->notify_one()` or `this->notify_all()`, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking `lock.lock()` before the call to `wait` returns. The lock is also reacquired by invoking `lock.lock()` if the function exits with an exception.

Postcondition: `lock` is locked by the current thread.

Throws: `boost::thread_resource_error` if an error occurs. `boost::thread_interrupted` if the wait was interrupted by a call to `interrupt()` on the `boost::thread` object associated with the current thread of execution.

### `template<typename lock_type,typename predicate_type> void wait(lock_type& lock, predicate_type pred)`

Effects: As-if

```
while(!pred())
{
    wait(lock);
}
```

### `template<typename lock_type> bool timed_wait(lock_type& lock,boost::system_time const& abs_time)`

Effects: Atomically call `lock.unlock()` and blocks the current thread. The thread will unblock when notified by a call to `this->notify_one()` or `this->notify_all()`, when the time as reported by `boost::get_system_time()` would be equal to or later than the specified `abs_time`, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking `lock.lock()` before the call to `wait` returns. The lock is also reacquired by invoking `lock.lock()` if the function exits with an exception.

Returns: `false` if the call is returning because the time specified by `abs_time` was reached, `true` otherwise.

Postcondition: `lock` is locked by the current thread.

Throws: `boost::thread_resource_error` if an error occurs. `boost::thread_interrupted` if the wait was interrupted by a call to `interrupt()` on the `boost::thread` object associated with the current thread of execution.

**`template<typename lock_type,typename duration_type> bool timed_wait(lock_type& lock,duration_type const& rel_time)`**

Effects: Atomically call `lock.unlock()` and blocks the current thread. The thread will unblock when notified by a call to `this->notify_one()` or `this->notify_all()`, after the period of time indicated by the `rel_time` argument has elapsed, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking `lock.lock()` before the call to `wait` returns. The lock is also reacquired by invoking `lock.lock()` if the function exits with an exception.

Returns: `false` if the call is returning because the time period specified by `rel_time` has elapsed, `true` otherwise.

Postcondition: `lock` is locked by the current thread.

Throws: `boost::thread_resource_error` if an error occurs. `boost::thread_interrupted` if the wait was interrupted by a call to `interrupt()` on the `boost::thread` object associated with the current thread of execution.

### Note

The duration overload of timed_wait is difficult to use correctly. The overload taking a predicate should be preferred in most cases.

**`template<typename lock_type,typename predicate_type> bool timed_wait(lock_type& lock, boost::system_time const& abs_time, predicate_type pred)`**

Effects: As-if

```
while(!pred())
{
    if(!timed_wait(lock,abs_time))
    {
        return pred();
    }
}
return true;
```

**`template <class lock_type, class Clock, class Duration> cv_status wait_until(lock_type& lock, const chrono::time_point<Clock, Duration>& abs_time)`**

Effects: Atomically call `lock.unlock()` and blocks the current thread. The thread will unblock when notified by a call to `this->notify_one()` or `this->notify_all()`, when the time as reported by `Clock::now()` would be equal to or later than the specified `abs_time`, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking `lock.lock()` before the call to `wait` returns. The lock is also reacquired by invoking `lock.lock()` if the function exits with an exception.

Returns: cv_status::timeout if the call is returning because the time specified by abs_time was reached, cv_status::no_timeout otherwise.

Postcondition: lock is locked by the current thread.

Throws: boost::thread_resource_error if an error occurs. boost::thread_interrupted if the wait was interrupted by a call to interrupt() on the boost::thread object associated with the current thread of execution.

**template <class lock_type, class Rep, class Period> cv_status wait_for(lock_type& lock, const chrono::duration<Rep, Period>& rel_time)**

Effects: Atomically call lock.unlock() and blocks the current thread. The thread will unblock when notified by a call to this->notify_one() or this->notify_all(), after the period of time indicated by the rel_time argument has elapsed, or spuriously. When the thread is unblocked (for whatever reason), the lock is reacquired by invoking lock.lock() before the call to wait returns. The lock is also reacquired by invoking lock.lock() if the function exits with an exception.

Returns: cv_status::timeout if the call is returning because the time specified by abs_time was reached, cv_status::no_timeout otherwise.

Postcondition: lock is locked by the current thread.

Throws: boost::thread_resource_error if an error occurs. boost::thread_interrupted if the wait was interrupted by a call to interrupt() on the boost::thread object associated with the current thread of execution.

### Note

The duration overload of timed_wait is difficult to use correctly. The overload taking a predicate should be preferred in most cases.

**template <class lock_type, class Clock, class Duration, class Predicate> bool wait_until(lock_type& lock, const chrono::time_point<Clock, Duration>& abs_time, Predicate pred)**

Effects: As-if

```
while(!pred())
{
    if(!wait_until(lock,abs_time))
    {
        return pred();
    }
}
return true;
```

**template <class lock_type, class Rep, class Period, class Predicate> bool wait_for(lock_type& lock, const chrono::duration<Rep, Period>& rel_time, Predicate pred)**

Effects: As-if

```
return wait_until(lock, chrono::steady_clock::now() + d, boost::move(pred));
```

## Typedef `condition` DEPRECATED V3

```
// #include <boost/thread/condition.hpp>
namespace boost
{

  typedef condition_variable_any condition;

}
```

The typedef `condition` is provided for backwards compatibility with previous boost releases.

## Non-member Function `notify_all_at_thread_exit`()

```
// #include <boost/thread/condition_variable.hpp>

namespace boost
{
  void notify_all_at_thread_exit(condition_variable& cond, unique_lock<mutex> lk);
}
```

Requires: `lk` is locked by the calling thread and either no other thread is waiting on `cond`, or `lk.mutex()` returns the same value for each of the lock arguments supplied by all concurrently waiting (via `wait`, `wait_for`, or `wait_until`) threads.

Effects: transfers ownership of the lock associated with `lk` into internal storage and schedules `cond` to be notified when the current thread exits, after all objects of thread storage duration associated with the current thread have been destroyed. This notification shall be as if

```
lk.unlock();
cond.notify_all();
```

# One-time Initialization

```
#include <boost/thread/once.hpp>

namespace boost
{
  struct once_flag;
  template<typename Callable>
  void call_once(once_flag& flag,Callable func);

#if defined BOOST_THREAD_PROVIDES_DEPRECATED_FEATURES_SINCE_V3_0_0
  void call_once(void (*func)(),once_flag& flag);
#endif

}
```

`boost::call_once` provides a mechanism for ensuring that an initialization routine is run exactly once without data races or deadlocks.

## Typedef `once_flag`

```
#ifdef BOOST_THREAD_PROVIDES_ONCE_CXX11
struct once_flag
{
  constexprr once_flag() noexcept;
  once_flag(const once_flag&) = delete;
  once_flag& operator=(const once_flag&) = delete;
};
#else
typedef platform-specific-type once_flag;
#define BOOST_ONCE_INIT platform-specific-initializer
#endif
```

Objects of type `boost::once_flag` shall be initialized with `BOOST_ONCE_INIT` if BOOST_THREAD_PROVIDES_ONCE_CXX11 is not defined

```
boost::once_flag f=BOOST_ONCE_INIT;
```

## Non-member function `call_once`

```
template<typename Callable>
void call_once(once_flag& flag,Callable func);
```

Requires: `Callable` is `CopyConstructible`. Copying `func` shall have no side effects, and the effect of calling the copy shall be equivalent to calling the original.

Effects: Calls to `call_once` on the same `once_flag` object are serialized. If there has been no prior effective `call_once` on the same `once_flag` object, the argument `func` (or a copy thereof) is called as-if by invoking `func()`, and the invocation of `call_once` is effective if and only if `func()` returns without exception. If an exception is thrown, the exception is propagated to the caller. If there has been a prior effective `call_once` on the same `once_flag` object, the `call_once` returns without invoking `func`.

Synchronization: The completion of an effective `call_once` invocation on a `once_flag` object, synchronizes with all subsequent `call_once` invocations on the same `once_flag` object.

Throws: `thread_resource_error` when the effects cannot be achieved. or any exception propagated from `func`.

Note: The function passed to `call_once` must not also call `call_once` passing the same `once_flag` object. This may cause deadlock, or invoking the passed function a second time. The alternative is to allow the second call to return immediately, but that assumes the code knows it has been called recursively, and can proceed even though the call to `call_once` didn't actually call the function, in which case it could also avoid calling `call_once` recursively.

```
void call_once(void (*func)(),once_flag& flag);
```

This second overload is provided for backwards compatibility. The effects of `call_once(func,flag)` shall be the same as those of `call_once(flag,func)`.

# Barriers

A barrier is a simple concept. Also known as a *rendezvous*, it is a synchronization point between multiple threads. The barrier is configured for a particular number of threads (`n`), and as threads reach the barrier they must wait until all `n` threads have arrived. Once the `n`-th thread has reached the barrier, all the waiting threads can proceed, and the barrier is reset.

## Class `barrier`

```
#include <boost/thread/barrier.hpp>

class barrier
{
public:
    barrier(unsigned int count);
    ~barrier();

    bool wait();
};
```

Instances of `boost::barrier` are not copyable or movable.

### Constructor

```
barrier(unsigned int count);
```

Effects: Construct a barrier for `count` threads.

Throws: `boost::thread_resource_error` if an error occurs.

### Destructor

```
~barrier();
```

Precondition: No threads are waiting on `*this`.

Effects: Destroys `*this`.

Throws: Nothing.

### Member function `wait`

```
bool wait();
```

Effects: Block until `count` threads have called `wait` on `*this`. When the `count`-th thread calls `wait`, all waiting threads are unblocked, and the barrier is reset.

Returns: `true` for exactly one thread from each batch of waiting threads, `false` otherwise.

Throws: `boost::thread_resource_error` if an error occurs.

# Futures

## Overview

The futures library provides a means of handling synchronous future values, whether those values are generated by another thread, or on a single thread in response to external stimuli, or on-demand.

This is done through the provision of four class templates: `future` and `boost::shared_future` which are used to retrieve the asynchronous results, and `boost::promise` and `boost::packaged_task` which are used to generate the asynchronous results.

An instance of `future` holds the one and only reference to a result. Ownership can be transferred between instances using the move constructor or move-assignment operator, but at most one instance holds a reference to a given asynchronous result. When the result is ready, it is returned from `boost::future<R>::get()` by rvalue-reference to allow the result to be moved or copied as appropriate for the type.

On the other hand, many instances of `boost::shared_future` may reference the same result. Instances can be freely copied and assigned, and `boost::shared_future<R>::get()` returns a non `const` reference so that multiple calls to `boost::shared_future<R>::get()` are safe. You can move an instance of `future` into an instance of `boost::shared_future`, thus transferring ownership of the associated asynchronous result, but not vice-versa.

`boost::async` is a simple way of running asynchronous tasks. A call to `boost::async` returns a `future` that will contain the result of the task.

You can wait for futures either individually or with one of the `boost::wait_for_any()` and `boost::wait_for_all()` functions.

## Creating asynchronous values

You can set the value in a future with either a `boost::promise` or a `boost::packaged_task`. A `boost::packaged_task` is a callable object that wraps a function or callable object. When the packaged task is invoked, it invokes the contained function in turn, and populates a future with the return value. This is an answer to the perennial question: "how do I return a value from a thread?": package the function you wish to run as a `boost::packaged_task` and pass the packaged task to the thread constructor. The future retrieved from the packaged task can then be used to obtain the return value. If the function throws an exception, that is stored in the future in place of the return value.

```
int calculate_the_answer_to_life_the_universe_and_everything()
{
    return 42;
}

boost::packaged_task<int> pt(calculate_the_answer_to_life_the_universe_and_everything);
boost:: future<int> fi=pt.get_future();

boost::thread task(boost::move(pt)); // launch task on a thread

fi.wait(); // wait for it to finish

assert(fi.is_ready());
assert(fi.has_value());
assert(!fi.has_exception());
assert(fi.get_state()==boost::future_state::ready);
assert(fi.get()==42);
```

A `boost::promise` is a bit more low level: it just provides explicit functions to store a value or an exception in the associated future. A promise can therefore be used where the value may come from more than one possible source, or where a single operation may produce multiple values.

```
boost::promise<int> pi;
boost:: future<int> fi;
fi=pi.get_future();

pi.set_value(42);

assert(fi.is_ready());
assert(fi.has_value());
assert(!fi.has_exception());
assert(fi.get_state()==boost::future_state::ready);
assert(fi.get()==42);
```

## Wait Callbacks and Lazy Futures

Both `boost::promise` and `boost::packaged_task` support *wait callbacks* that are invoked when a thread blocks in a call to `wait()` or `timed_wait()` on a future that is waiting for the result from the `boost::promise` or `boost::packaged_task`, in the thread that is doing the waiting. These can be set using the `set_wait_callback()` member function on the `boost::promise` or `boost::packaged_task` in question.

This allows *lazy futures* where the result is not actually computed until it is needed by some thread. In the example below, the call to `f.get()` invokes the callback `invoke_lazy_task`, which runs the task to set the value. If you remove the call to `f.get()`, the task is not ever run.

```
int calculate_the_answer_to_life_the_universe_and_everything()
{
    return 42;
}

void invoke_lazy_task(boost::packaged_task<int>& task)
{
    try
    {
        task();
    }
    catch(boost::task_already_started&)
    {}
}

int main()
{
    boost::packaged_task<int> task(calculate_the_answer_to_life_the_universe_and_everything);
    task.set_wait_callback(invoke_lazy_task);
    boost:: future<int> f(task.get_future());

    assert(f.get()==42);
}
```

## Handling Detached Threads and Thread Specific Variables

Detached threads pose a problem for objects with thread storage duration. If we use a mechanism other than `thread::__join` to wait for a `thread` to complete its work - such as waiting for a future to be ready - then the destructors of thread specific variables will still be running after the waiting thread has resumed. This section explain how the standard mechanism can be used to make such synchronization safe by ensuring that the objects with thread storage duration are destroyed prior to the future being made ready. e.g.

```
int find_the_answer(); // uses thread specific objects
void thread_func(boost::promise<int>&& p)
{
    p.set_value_at_thread_exit(find_the_answer());
}

int main()
{
    boost::promise<int> p;
    boost::thread t(thread_func,boost::move(p));
    t.detach(); // we're going to wait on the future
    std::cout<<p.get_future().get()<<std::endl;
}
```

When the call to `get()` returns, we know that not only is the future value ready, but the thread specific variables on the other thread have also been destroyed.

Such mechanisms are provided for `boost::condition_variable`, `boost::promise` and `boost::packaged_task`. e.g.

```
void task_executor(boost::packaged_task<void(int)> task,int param)
{
    task.make_ready_at_thread_exit(param); // execute stored task
} // destroy thread specific and wake threads waiting on futures from task
```

Other threads can wait on a future obtained from the task without having to worry about races due to the execution of destructors of the thread specific objects from the task's thread.

```
boost::condition_variable cv;
boost::mutex m;
complex_type the_data;
bool data_ready;

void thread_func()
{
    boost::unique_lock<std::mutex> lk(m);
    the_data=find_the_answer();
    data_ready=true;
    boost::notify_all_at_thread_exit(cv,boost::move(lk));
} // destroy thread specific objects, notify cv, unlock mutex

void waiting_thread()
{
    boost::unique_lock<std::mutex> lk(m);
    while(!data_ready)
    {
        cv.wait(lk);
    }
    process(the_data);
}
```

The waiting thread is guaranteed that the thread specific objects used by `thread_func()` have been destroyed by the time `process(the_data)` is called. If the lock on `m` is released and re-acquired after setting `data_ready` and before calling `boost::notify_all_at_thread_exit()` then this does NOT hold, since the thread may return from the wait due to a spurious wake-up.

## Executing asynchronously

`boost::async` is a simple way of running asynchronous tasks to make use of the available hardware concurrency. A call to `boost::async` returns a `boost::future` that will contain the result of the task. Depending on the launch policy, the task is either run asynchronously on its own thread or synchronously on whichever thread calls the `wait()` or `get()` member functions on that `future`.

A launch policy of either boost::launch::async, which asks the runtime to create an asynchronous thread, or boost::launch::deferred, which indicates you simply want to defer the function call until a later time (lazy evaluation). This argument is optional - if you omit it your function will use the default policy.

For example, consider computing the sum of a very large array. The first task is to not compute asynchronously when the overhead would be significant. The second task is to split the work into two pieces, one executed by the host thread and one executed asynchronously.

```
int parallel_sum(int* data, int size)
{
  int sum = 0;
  if ( size < 1000 )
    for ( int i = 0; i < size; ++i )
      sum += data[i];
  else {
    auto handle = boost::async(parallel_sum, data+size/2, size-size/2);
    sum += parallel_sum(data, size/2);
    sum += handle.get();
  }
  return sum;
}
```

# Shared Futures

`shared_future` is designed to be shared between threads, that is to allow multiple concurrent get operations.

## Multiple get

The second `get()` call in the following example future

```
void bad_second_use( type arg ) {

  auto ftr = async( [=]{ return work( arg ); } );
    if ( cond1 )
    {
        use1( ftr.get() );
    } else
    {
        use2( ftr.get() );
    }
    use3( ftr.get() ); // second use is undefined
}
```

Using a `shared_mutex` solves the issue

```
void good_second_use( type arg ) {

   shared_future<type> ftr = async( [=]{ return work( arg ); } );
    if ( cond1 )
    {
        use1( ftr.get() );
    } else
    {
        use2(  ftr.get() );
    }
    use3( ftr.get() ); // second use is defined
}
```

## share()

Namming the return type when declaring the `shared_future` is needed; auto is not available within template argument lists. Here `share()` could be used to simplify the code

```
void better_second_use( type arg ) {

   auto ftr = async( [=]{ return work( arg ); } ).share();
    if ( cond1 )
    {
        use1( ftr.get() );
    } else
    {
        use2(  ftr.get() );
    }
    use3( ftr.get() ); // second use is defined
}
```

### Writting on get()

The user can either read or write the future avariable.

```
void write_to_get( type arg ) {

   auto ftr = async( [=]{ return work( arg ); } ).share();
    if ( cond1 )
    {
        use1( ftr.get() );
    } else
    {
      if ( cond2 )
        use2(  ftr.get() );
      else
        ftr.get() = something(); // assign to non-const reference.
    }
    use3( ftr.get() ); // second use is defined
}
```

This works because the `shared_future<>::get()` function returns a non-const reference to the appropriate storage. Of course the access to this storage must be ensured by the user. The library doesn't ensure the access to the internal storage is thread safe.

There has been some work by the C++ standard committe on an `atomic_future` that behaves as an `atomic` variable, that is is thread_safe, and a `shared_future` that can be shared between several threads, but there were not enough consensus and time to get it ready for C++11.

## Making immediate futures easier

Some functions may know the value at the point of construction. In these cases the value is immediately available, but needs to be returned as a future or shared_future. By using make_future (make_shared_future) a future (shared_future) can be created which holds a pre-computed result in its shared state.

Without these features it is non-trivial to create a future directly from a value. First a promise must be created, then the promise is set, and lastly the future is retrieved from the promise. This can now be done with one operation.

### make_future / make_shared_future

This function creates a future for a given value. If no value is given then a future<void> is returned. This function is primarily useful in cases where sometimes, the return value is immediately available, but sometimes it is not. The example below illustrates, that in an error path the value is known immediately, however in other paths the function must return an eventual value represented as a future.

```
boost::future<int> compute(int x)
{
  if (x == 0) return boost::make_future(0);
  if (x < 0) return boost::make_future(-1);
  boost::future<int> f1 = boost::async([]() { return x+1; });
  return f1;
}
```

There are two variations of this function. The first takes a value of any type, and returns a future of that type. The input value is passed to the shared state of the returned future. The second version takes no input and returns a future<void>. make_shared_future has the same functionality as make_future, except has a return type of shared_future.

## Associating future continuations

In asynchronous programming, it is very common for one asynchronous operation, on completion, to invoke a second operation and pass data to it. The current C++ standard does not allow one to register a continuation to a future. With .then, instead of waiting for the result, a continuation is "attached" to the asynchronous operation, which is invoked when the result is ready. Continuations registered using the .then function will help to avoid blocking waits or wasting threads on polling, greatly improving the responsiveness and scalability of an application.

future.then provides the ability to sequentially compose two futures by declaring one to be the continuation of another. With .then the antecedent future is ready (has a value or exception stored in the shared state) before the continuation starts as instructed by the lambda function.

In the example below the future<int> f2 is registered to be a continuation of future<int> f1 using the .then member function. This operation takes a lambda function which describes how f2 should proceed after f1 is ready.

```
#include <boost/thread/future.hpp>
using namespace boost;
int main()
{
  future<int> f1 = async([]() { return 123; });
  future<string> f2 = f1.then([](future<int> f) { return f.get().to_string(); // here .get() ↵
won't block });
}
```

One key feature of this function is the ability to chain multiple asynchronous operations. In asynchronous programming, it's common to define a sequence of operations, in which each continuation executes only when the previous one completes. In some cases, the antecedent future produces a value that the continuation accepts as input. By using future.then, creating a chain of continuations becomes straightforward and intuitive:

```
myFuture.then(...).then(...).then(...).
```

Some points to note are:

- Each continuation will not begin until the preceding has completed.
- If an exception is thrown, the following continuation can handle it in a try-catch block

Input Parameters:

- Lambda function2: One option which was considered was to follow JavaScript's approach and take two functions, one for success and one for error handling. However this option is not viable in C++ as there is no single base type for exceptions as there is in JavaScript. The lambda function takes a future as its input which carries the exception through. This makes propagating exceptions straightforward. This approach also simplifies the chaining of continuations.

- Scheduler: Providing an overload to .then, to take a scheduler reference places great flexibility over the execution of the future in the programmer's hand. As described above, often taking a launch policy is not sufficient for powerful asynchronous operations. The lifetime of the scheduler must outlive the continuation.
- Launch policy: if the additional flexibility that the scheduler provides is not required.

Return values: The decision to return a future was based primarily on the ability to chain multiple continuations using .then. This benefit of composability gives the programmer incredible control and flexibility over their code. Returning a future object rather than a shared_future is also a much cheaper operation thereby improving performance. A shared_future object is not necessary to take advantage of the chaining feature. It is also easy to go from a future to a shared_future when needed using future::share().

## Futures Reference

```
//#include <boost/thread/futures.hpp>

namespace boost
{
  namespace future_state  // EXTENSION
  {
    enum state {uninitialized, waiting, ready, moved};
  }

  enum class future_errc
  {
    broken_promise,
    future_already_retrieved,
    promise_already_satisfied,
    no_state
  };

  enum class launch
  {
    async = unspecified,
    deferred = unspecified,
    any = async | deferred
  };

  enum class future_status {
    ready,  timeout, deferred
  };

  namespace system
  {
    template <>
    struct is_error_code_enum<future_errc> : public true_type {};

    error_code make_error_code(future_errc e);

    error_condition make_error_condition(future_errc e);
  }

  const system::error_category& future_category();

  class future_error;

  template <typename R>
  class promise;

  template <typename R>
  void swap(promise<R>& x, promise<R>& y) noexcept;

  namespace container {
```

```
    template <class R, class Alloc>
    struct uses_allocator<promise<R>, Alloc>:: true_type;
  }

  template <typename R>
  class future;

  template <typename R>
  class shared_future;

  template <typename S>
  class packaged_task;
  template <class S> void swap(packaged_task<S>&, packaged_task<S>&) noexcept;

  template <class S, class Alloc>
  struct uses_allocator<packaged_task <S>, Alloc>;

  template <class F>
  future<typename result_of<typename decay<F>::type()>::type>
  async(F f);
  template <class F>
  future<typename result_of<typename decay<F>::type()>::type>
  async(launch policy, F f);

  template <class F, class... Args>
  future<typename result_of<typename decay<F>::type(typename decay<Args>::type...)>::type>
  async(F&& f, Args&&... args);
  template <class F, class... Args>
  future<typename result_of<typename decay<F>::type(typename decay<Args>::type...)>::type>
  async(launch policy, F&& f, Args&&... args);

  template<typename Iterator>
  void wait_for_all(Iterator begin,Iterator end); // EXTENSION
  template<typename F1,typename... FS>
  void wait_for_all(F1& f1,Fs&... fs); // EXTENSION

  template<typename Iterator>
  Iterator wait_for_any(Iterator begin,Iterator end);
  template<typename F1,typename... Fs>
  unsigned wait_for_any(F1& f1,Fs&... fs);

  template <typename T>
  future<typename decay<T>::type> make_future(T&& value);  // EXTENSION
  future<void> make_future();  // EXTENSION

  template <typename T>
  shared_future<typename decay<T>::type> make_shared_future(T&& value);  // EXTENSION
  shared_future<void> make_shared_future();  // EXTENSION
```

## Enumeration `state`

```
namespace future_state
{
  enum state {uninitialized, waiting, ready, moved};
}
```

## Enumeration `future_errc`

```
 enum class future_errc
 {
   broken_promise = implementation defined,
   future_already_retrieved = implementation defined,
   promise_already_satisfied = implementation defined,
   no_state = implementation defined
 }


The enum values of future_errc are distinct and not zero.
```

## Enumeration `launch`

```
enum class launch
{
  async = unspecified,
  deferred = unspecified,
  any = async | deferred
};
```

The enum type launch is a bitmask type with launch::async and launch::deferred denoting individual bits.

## Specialization `is_error_code_enum<future_errc>`

```
namespace system
{
  template <>
  struct is_error_code_enum<future_errc> : public true_type {};

}
```

## Non-member function `make_error_code()`

```
namespace system
{
  error_code make_error_code(future_errc e);
}
```

Returns: `error_code(static_cast<int>(e), future_category())`.

## Non-member function `make_error_condition()`

```
namespace system
{
  error_condition make_error_condition(future_errc e);
}
```

Returns: `error_condition(static_cast<int>(e), future_category())`.

## Non-member function `future_category()`

```
const system::error_category& future_category();
```

Returns: A reference to an object of a type derived from class error_category.

Notes: The object's `default_error_condition` and equivalent virtual functions behave as specified for the class `system::error_category`. The object's `name` virtual function returns a pointer to the string "future".

## Class `future_error`

```
class future_error
    : public std::logic_error
{
public:
    future_error(system::error_code ec);

    const system::error_code& code() const no_except;
};
```

### Constructor

```
future_error(system::error_code ec);
```

Effects: Constructs a future_error.

Postconditions: `code()==ec`

Throws: Nothing.

### Member function `code()`

```
const system::error_code& code() const no_except;
```

Returns: The value of `ec` that was passed to the object's constructor.

## Enumeration `future_status`

```
enum class future_status {
  ready,  timeout, deferred
};
```

## `future` class template

```
template <typename R>
class  future
{

public:
   future( future & rhs);// = delete;
   future& operator=( future& rhs);// = delete;

   future() noexcept;
  ~ future();

  // move support
   future( future && other) noexcept;
   future& operator=( future && other) noexcept;
  shared_future<R> share();
  template<typename F>
   future<typename boost::result_of<F( future&)>::type>
  then(F&& func); // EXTENSION
  template<typename S, typename F>
   future<typename boost::result_of<F( future&)>::type>
  then(S& scheduler, F&& func); // EXTENSION NOT_YET_IMPLEMENTED
  template<typename F>
   future<typename boost::result_of<F( future&)>::type>
  then(launch policy, F&& func); // EXTENSION NOT_YET_IMPLEMENTED

  void swap( future& other) noexcept; // EXTENSION

  // retrieving the value
  R&& get();

  // functions to check state
  bool valid() const noexcept;
  bool is_ready() const; // EXTENSION
  bool has_exception() const; // EXTENSION
  bool has_value() const; // EXTENSION

  // waiting for the result to be ready
  void wait() const;
  template <class Rep, class Period>
  future_status wait_for(const chrono::duration<Rep, Period>& rel_time) const;
  template <class Clock, class Duration>
  future_status wait_until(const chrono::time_point<Clock, Duration>& abs_time) const;

#if defined BOOST_THREAD_USES_DATE_TIME || defined BOOST_THREAD_DONT_USE_CHRONO
  template<typename Duration>
  bool timed_wait(Duration const& rel_time) const; // DEPRECATED SINCE V3.0.0
  bool timed_wait_until(boost::system_time const& abs_time) const; // DEPRECATED SINCE V3.0.0
#endif
  typedef future_state::state state;  // EXTENSION
  state get_state() const;  // EXTENSION
};
```

### Default Constructor

```
future();
```

Effects: Constructs an uninitialized `future`.

Postconditions: this->is_ready returns false. this->get_state() returns boost::future_state::uninitialized.

Throws: Nothing.

#### Destructor

```
~ future();
```

Effects: Destroys *this.

Throws: Nothing.

#### Move Constructor

```
future( future && other);
```

Effects: Constructs a new future, and transfers ownership of the asynchronous result associated with other to *this.

Postconditions: this->get_state() returns the value of other->get_state() prior to the call. other->get_state() returns boost::future_state::uninitialized. If other was associated with an asynchronous result, that result is now associated with *this. other is not associated with any asynchronous result.

Throws: Nothing.

Notes: If the compiler does not support rvalue-references, this is implemented using the boost.thread move emulation.

#### Move Assignment Operator

```
future& operator=( future && other);
```

Effects: Transfers ownership of the asynchronous result associated with other to *this.

Postconditions: this->get_state() returns the value of other->get_state() prior to the call. other->get_state() returns boost::future_state::uninitialized. If other was associated with an asynchronous result, that result is now associated with *this. other is not associated with any asynchronous result. If *this was associated with an asynchronous result prior to the call, that result no longer has an associated future instance.

Throws: Nothing.

Notes: If the compiler does not support rvalue-references, this is implemented using the boost.thread move emulation.

#### Member function swap()

```
void swap( future & other) no_except;
```

Effects: Swaps ownership of the asynchronous results associated with other and *this.

Postconditions: this->get_state() returns the value of other->get_state() prior to the call. other->get_state() returns the value of this->get_state() prior to the call. If other was associated with an asynchronous result, that result is now associated with *this, otherwise *this has no associated result. If *this was associated with an asynchronous result, that result is now associated with other, otherwise other has no associated result.

Throws: Nothing.

### Member function `get()`

```
R&& get();
R&  future<R&>::get();
void  future<void>::get();
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready as-if by a call to `boost::future<R>::wait()`, and retrieves the result (whether that is a value or an exception).

Returns: If the result type `R` is a reference, returns the stored reference. If `R` is `void`, there is no return value. Otherwise, returns an rvalue-reference to the value stored in the asynchronous result.

Postconditions: `this->is_ready()` returns `true`. `this->get_state()` returns `boost::future_state::ready`.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception stored in the asynchronous result in place of a value.

Notes: `get()` is an *interruption point*.

### Member function `wait()`

```
void wait() const;
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: `this->is_ready()` returns `true`. `this->get_state()` returns `boost::future_state::ready`.

Notes: `wait()` is an *interruption point*.

### Member function `timed_wait()` DEPRECATED SINCE V3.0.0

```
template<typename Duration>
bool timed_wait(Duration const& wait_duration);
```

**Warning**

DEPRECATED since 3.00.

Available only up to Boost 1.56.

Use instead `wait_for`.

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready, or the time specified by `wait_duration` has elapsed. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Returns: `true` if `*this` is associated with an asynchronous result, and that result is ready before the specified time has elapsed, `false` otherwise.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: If this call returned `true`, then `this->is_ready()` returns `true` and `this->get_state()` returns `boost::future_state::ready`.

Notes: `timed_wait()` is an *interruption point*. `Duration` must be a type that meets the Boost.DateTime time duration requirements.

#### Member function `timed_wait()` DEPRECATED SINCE V3.0.0

```
bool timed_wait(boost::system_time const& wait_timeout);
```

**Warning**

DEPRECATED since 3.00.

Available only up to Boost 1.56.

Use instead `wait_until`.

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready, or the time point specified by `wait_timeout` has passed. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Returns: `true` if `*this` is associated with an asynchronous result, and that result is ready before the specified time has passed, `false` otherwise.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: If this call returned `true`, then `this->is_ready()` returns `true` and `this->get_state()` returns `boost::future_state::ready`.

Notes: `timed_wait()` is an *interruption point*.

#### Member function `wait_for()`

```
template <class Rep, class Period>
future_status wait_for(const chrono::duration<Rep, Period>& rel_time) const;
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready, or the time specified by `wait_duration` has elapsed. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Returns: - `future_status::deferred` if the shared state contains a deferred function. (Not implemented yet)

- `future_status::ready` if the shared state is ready.

- `future_status::timeout` if the function is returning because the relative timeout specified by `rel_time` has expired.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: If this call returned `true`, then `this->is_ready()` returns `true` and `this->get_state()` returns `boost::future_state::ready`.

Notes: `wait_for()` is an *interruption point*. `Duration` must be a type that meets the Boost.DateTime time duration requirements.

### Member function `wait_until()`

```
template <class Clock, class Duration>
future_status wait_until(const chrono::time_point<Clock, Duration>& abs_time) const;
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready, or the time point specified by `wait_timeout` has passed. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Returns: - `future_status::deferred` if the shared state contains a deferred function. (Not implemented yet)

- `future_status::ready` if the shared state is ready.

- `future_status::timeout` if the function is returning because the absolute timeout specified by `absl_time` has reached.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: If this call returned `true`, then `this->is_ready()` returns `true` and `this->get_state()` returns `boost::future_state::ready`.

Notes: `wait_until()` is an *interruption point*.

### Member function `valid()`

```
bool valid() const noexcept;
```

Returns: `true` if `*this` is associated with an asynchronous result, `false` otherwise.

Throws: Nothing.

### Member function `is_ready()` EXTENSION

```
bool is_ready() const;
```

Returns: `true` if `*this` is associated with an asynchronous result and that result is ready for retrieval, `false` otherwise.

Throws: Nothing.

### Member function `has_value()` EXTENSION

```
bool has_value() const;
```

Returns: `true` if `*this` is associated with an asynchronous result, that result is ready for retrieval, and the result is a stored value, `false` otherwise.

Throws: Nothing.

### Member function `has_exception()` EXTENSION

```
bool has_exception() const;
```

Returns: `true` if `*this` is associated with an asynchronous result, that result is ready for retrieval, and the result is a stored exception, `false` otherwise.

Throws: Nothing.

### Member function `get_state()`

```
future_state::state get_state();
```

Effects: Determine the state of the asynchronous result associated with `*this`, if any.

Returns: `boost::future_state::uninitialized` if `*this` is not associated with an asynchronous result. `boost::future_state::ready` if the asynchronous result associated with `*this` is ready for retrieval, `boost::future_state::waiting` otherwise.

Throws: Nothing.

### Member function `then()`

```
template<typename F>
 future<typename boost::result_of<F( future&)>::type>
then(F&& func); // EXTENSION
template<typename S, typename F>
 future<typename boost::result_of<F( future&)>::type>
then(S& scheduler, F&& func); // EXTENSION
template<typename F>
 future<typename boost::result_of<F( future&)>::type>
then(launch policy, F&& func); // EXTENSION
```

Notes: The three functions differ only by input parameters. The first only takes a callable object which accepts a future object as a parameter. The second function takes a scheduler as the first parameter and a callable object as the second parameter. The third function takes a launch policy as the first parameter and a callable object as the second parameter.

Effects: - The continuation is called when the object's shared state is ready (has a value or exception stored).

- The continuation launches according to the specified policy or scheduler.

- When the scheduler or launch policy is not provided the continuation inherits the parent's launch policy or scheduler.

- If the parent was created with std::promise or with a packaged_task (has no associated launch policy), the continuation behaves the same as the third overload with a policy argument of launch::async | launch::deferred and the same argument for func.

- If the parent has a policy of launch::deferred and the continuation does not have a specified launch policy or scheduler, then the parent is filled by immediately calling .wait(), and the policy of the antecedent is launch::deferred

Returns: An object of type future<decltype(func(*this))> that refers to the shared state created by the continuation.

Postconditions: - The future object is moved to the parameter of the continuation function .

- valid() == false on original future object immediately after it returns.

## `shared_future` class template

```
template <typename R>
class shared_future
{
public:
  typedef future_state::state state; // EXTENSION

  shared_future() noexcept;
  ~shared_future();

  // copy support
  shared_future(shared_future const& other);
  shared_future& operator=(shared_future const& other);

  // move support
  shared_future(shared_future && other) noexcept;
  shared_future( future<R> && other) noexcept;
  shared_future& operator=(shared_future && other) noexcept;
  shared_future& operator=( future<R> && other) noexcept;

  void swap(shared_future& other);

  // retrieving the value
  R get();

  // functions to check state, and wait for ready
  bool valid() const noexcept;
  bool is_ready() const noexcept; // EXTENSION
  bool has_exception() const noexcept; // EXTENSION
  bool has_value() const noexcept; // EXTENSION

  // waiting for the result to be ready
  void wait() const;
  template <class Rep, class Period>
  future_status wait_for(const chrono::duration<Rep, Period>& rel_time) const;
  template <class Clock, class Duration>
  future_status wait_until(const chrono::time_point<Clock, Duration>& abs_time) const;

#if defined BOOST_THREAD_USES_DATE_TIME || defined BOOST_THREAD_DONT_USE_CHRONO
  template<typename Duration>
  bool timed_wait(Duration const& rel_time) const;  // DEPRECATED SINCE V3.0.0
  bool timed_wait_until(boost::system_time const& abs_time) const;  // DEPRECATED SINCE V3.0.0
#endif
  state get_state() const noexcept;  // EXTENSION
};
```

### Default Constructor

```
shared_future();
```

Effects: Constructs an uninitialized shared_future.

Postconditions: `this->is_ready` returns `false`. `this->get_state()` returns `boost::future_state::uninitialized`.

Throws: Nothing.

### Member function `get()`

```
const R& get();
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready as-if by a call to `boost::shared_future<R>::wait()`, and returns a `const` reference to the result.

Returns: If the result type `R` is a reference, returns the stored reference. If `R` is `void`, there is no return value. Otherwise, returns a `const` reference to the value stored in the asynchronous result.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

Notes: `get()` is an *interruption point*.

### Member function `wait()`

```
void wait() const;
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: `this->is_ready()` returns `true`. `this->get_state()` returns `boost::future_state::ready`.

Notes: `wait()` is an *interruption point*.

### Member function `timed_wait()`

```
template<typename Duration>
bool timed_wait(Duration const& wait_duration);
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready, or the time specified by `wait_duration` has elapsed. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Returns: `true` if `*this` is associated with an asynchronous result, and that result is ready before the specified time has elapsed, `false` otherwise.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: If this call returned `true`, then `this->is_ready()` returns `true` and `this->get_state()` returns `boost::future_state::ready`.

Notes: `timed_wait()` is an *interruption point*. `Duration` must be a type that meets the Boost.DateTime time duration requirements.

### Member function `timed_wait()`

```
bool timed_wait(boost::system_time const& wait_timeout);
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready, or the time point specified by `wait_timeout` has passed. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Returns: `true` if `*this` is associated with an asynchronous result, and that result is ready before the specified time has passed, `false` otherwise.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: If this call returned `true`, then `this->is_ready()` returns `true` and `this->get_state()` returns `boost::future_state::ready`.

Notes: `timed_wait()` is an *interruption point*.

### Member function `wait_for()`

```
template <class Rep, class Period>
future_status wait_for(const chrono::duration<Rep, Period>& rel_time) const;
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready, or the time specified by `wait_duration` has elapsed. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Returns: - `future_status::deferred` if the shared state contains a deferred function. (Not implemented yet)

- `future_status::ready` if the shared state is ready.

- `future_status::timeout` if the function is returning because the relative timeout specified by `rel_time` has expired.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: If this call returned `true`, then `this->is_ready()` returns `true` and `this->get_state()` returns `boost::future_state::ready`.

Notes: `timed_wait()` is an *interruption point*. `Duration` must be a type that meets the Boost.DateTime time duration requirements.

#### Member function `wait_until()`

```
template <class Clock, class Duration>
future_status wait_until(const chrono::time_point<Clock, Duration>& abs_time) const;
```

Effects: If `*this` is associated with an asynchronous result, waits until the result is ready, or the time point specified by `wait_timeout` has passed. If the result is not ready on entry, and the result has a *wait callback* set, that callback is invoked prior to waiting.

Returns: - `future_status::deferred` if the shared state contains a deferred function. (Not implemented yet)

- `future_status::ready` if the shared state is ready.

- `future_status::timeout` if the function is returning because the absolute timeout specified by `absl_time` has reached.

Throws: - `boost::future_uninitialized` if `*this` is not associated with an asynchronous result.

- `boost::thread_interrupted` if the result associated with `*this` is not ready at the point of the call, and the current thread is interrupted.

- Any exception thrown by the *wait callback* if such a callback is called.

Postconditions: If this call returned `true`, then `this->is_ready()` returns `true` and `this->get_state()` returns `boost::future_state::ready`.

Notes: `timed_wait()` is an *interruption point*.

#### Member function `valid()`

```
bool valid() const noexcept;
```

Returns: `true` if `*this` is associated with an asynchronous result, `false` otherwise.

Throws: Nothing.

#### Member function `is_ready()` EXTENSION

```
bool is_ready() const;
```

Returns: `true` if `*this` is associated with an asynchronous result, and that result is ready for retrieval, `false` otherwise.

Throws: Nothing.

#### Member function `has_value()` EXTENSION

```
bool has_value() const;
```

Returns: `true` if `*this` is associated with an asynchronous result, that result is ready for retrieval, and the result is a stored value, `false` otherwise.

Throws: Nothing.

### Member function `has_exception()` EXTENSION

```
bool has_exception() const;
```

Returns: `true` if `*this` is associated with an asynchronous result, that result is ready for retrieval, and the result is a stored exception, `false` otherwise.

Throws: Nothing.

### Member function `get_state()`

```
future_state::state get_state();
```

Effects: Determine the state of the asynchronous result associated with `*this`, if any.

Returns: `boost::future_state::uninitialized` if `*this` is not associated with an asynchronous result. `boost::future_state::ready` if the asynchronous result associated with `*this` is ready for retrieval, `boost::future_state::waiting` otherwise.

Throws: Nothing.

## `promise` class template

```
template <typename R>
class promise
{
public:

  promise();
  template <class Allocator>
  promise(allocator_arg_t, Allocator a);
  promise & operator=(const promise & rhs);// = delete;
  promise(const promise & rhs);// = delete;
  ~promise();

  // Move support
  promise(promise && rhs) noexcept;;
  promise & operator=(promise&& rhs) noexcept;;

  void swap(promise& other) noexcept;
  // Result retrieval
   future<R> get_future();

  // Set the value
  void set_value(see below);
  void set_exception(boost::exception_ptr e);

  // setting the result with deferred notification
  void set_value_at_thread_exit(see below);
  void set_exception_at_thread_exit(exception_ptr p);

  template<typename F>
  void set_wait_callback(F f); // EXTENSION
};
```

### Default Constructor

```
promise();
```

Effects: Constructs a new `boost::promise` with no associated result.

Throws: Nothing.

### Allocator Constructor

```
template <class Allocator>
promise(allocator_arg_t, Allocator a);
```

Effects: Constructs a new `boost::promise` with no associated result using the allocator `a`.

Throws: Nothing.

Notes: Available only if BOOST_THREAD_FUTURE_USES_ALLOCATORS is defined.

### Move Constructor

```
promise(promise && other);
```

Effects: Constructs a new `boost::promise`, and transfers ownership of the result associated with `other` to `*this`, leaving `other` with no associated result.

Throws: Nothing.

Notes: If the compiler does not support rvalue-references, this is implemented using the boost.thread move emulation.

### Move Assignment Operator

```
promise& operator=(promise && other);
```

Effects: Transfers ownership of the result associated with `other` to `*this`, leaving `other` with no associated result. If there was already a result associated with `*this`, and that result was not *ready*, sets any futures associated with that result to *ready* with a `boost::broken_promise` exception as the result.

Throws: Nothing.

Notes: If the compiler does not support rvalue-references, this is implemented using the boost.thread move emulation.

### Destructor

```
~promise();
```

Effects: Destroys `*this`. If there was a result associated with `*this`, and that result is not *ready*, sets any futures associated with that task to *ready* with a `boost::broken_promise` exception as the result.

Throws: Nothing.

### Member Function `get_future()`

```
future<R> get_future();
```

Effects: If `*this` was not associated with a result, allocate storage for a new asynchronous result and associate it with `*this`. Returns a `future` associated with the result associated with `*this`.

Throws: `boost::future_already_retrieved` if the future associated with the task has already been retrieved. `std::bad_alloc` if any memory necessary could not be allocated.

### Member Function `set_value()`

```
void set_value(R&& r);
void set_value(const R& r);
void promise<R&>::set_value(R& r);
void promise<void>::set_value();
```

Effects: - If BOOST_THREAD_PROVIDES_PROMISE_LAZY is defined and if `*this` was not associated with a result, allocate storage for a new asynchronous result and associate it with `*this`.

- Store the value `r` in the asynchronous result associated with `*this`. Any threads blocked waiting for the asynchronous result are woken.

Postconditions: All futures waiting on the asynchronous result are *ready* and `boost::future<R>::has_value()` or `boost::shared_future<R>::has_value()` for those futures shall return `true`.

Throws: - `boost::promise_already_satisfied` if the result associated with `*this` is already *ready*.

- `boost::broken_promise` if `*this` has no shared state.

- `std::bad_alloc` if the memory required for storage of the result cannot be allocated.

- Any exception thrown by the copy or move-constructor of `R`.

### Member Function `set_exception()`

```
void set_exception(boost::exception_ptr e);
```

Effects: - If BOOST_THREAD_PROVIDES_PROMISE_LAZY is defined and if `*this` was not associated with a result, allocate storage for a new asynchronous result and associate it with `*this`.

- Store the exception `e` in the asynchronous result associated with `*this`. Any threads blocked waiting for the asynchronous result are woken.

Postconditions: All futures waiting on the asynchronous result are *ready* and `boost::future<R>::has_exception()` or `boost::shared_future<R>::has_exception()` for those futures shall return `true`.

Throws: - `boost::promise_already_satisfied` if the result associated with `*this` is already *ready*.

- `boost::broken_promise` if `*this` has no shared state.

- `std::bad_alloc` if the memory required for storage of the result cannot be allocated.

### Member Function `set_value_at_thread_exit()`

```
void set_value_at_thread_exit(R&& r);
void set_value_at_thread_exit(const R& r);
void promise<R&>::set_value_at_thread_exit(R& r);
void promise<void>::set_value_at_thread_exit();
```

Effects: Stores the value r in the shared state without making that state ready immediately. Schedules that state to be made ready when the current thread exits, after all objects of thread storage duration associated with the current thread have been destroyed.

Throws:
- `boost::promise_already_satisfied` if the result associated with `*this` is already *ready*.
- `boost::broken_promise` if `*this` has no shared state.
- `std::bad_alloc` if the memory required for storage of the result cannot be allocated.
- Any exception thrown by the copy or move-constructor of `R`.

### Member Function `set_exception_at_thread_exit()`

```
void set_exception_at_thread_exit(boost::exception_ptr e);
```

Effects: Stores the exception pointer p in the shared state without making that state ready immediately. Schedules that state to be made ready when the current thread exits, after all objects of thread storage duration associated with the current thread have been destroyed.

Postconditions: All futures waiting on the asynchronous result are *ready* and `boost::future<R>::has_exception()` or `boost::shared_future<R>::has_exception()` for those futures shall return `true`.

Throws:
- `boost::promise_already_satisfied` if the result associated with `*this` is already *ready*.
- `boost::broken_promise` if `*this` has no shared state.
- `std::bad_alloc` if the memory required for storage of the result cannot be allocated.

### Member Function `set_wait_callback()` EXTENSION

```
template<typename F>
void set_wait_callback(F f);
```

Preconditions: The expression `f(t)` where `t` is a lvalue of type `boost::promise` shall be well-formed. Invoking a copy of `f` shall have the same effect as invoking `f`

Effects: Store a copy of `f` with the asynchronous result associated with `*this` as a *wait callback*. This will replace any existing wait callback store alongside that result. If a thread subsequently calls one of the wait functions on a `future` or `boost::shared_future` associated with this result, and the result is not *ready*, `f(*this)` shall be invoked.

Throws: `std::bad_alloc` if memory cannot be allocated for the required storage.

## `packaged_task` class template

```
template<typename S>
class packaged_task;
template<typename R
  , class... ArgTypes
>
class packaged_task<R(ArgTypes)>
{
public:
  packaged_task(packaged_task&);// = delete;
  packaged_task& operator=(packaged_task&);// = delete;

  // construction and destruction
  packaged_task() noexcept;

  explicit packaged_task(R(*f)(ArgTypes...));

  template <class F>
  explicit packaged_task(F&& f);

  template <class Allocator>
  packaged_task(allocator_arg_t, Allocator a, R(*f)(ArgTypes...));
  template <class F, class Allocator>
  packaged_task(allocator_arg_t, Allocator a, F&& f);

  ~packaged_task()
  {}

  // move support
  packaged_task(packaged_task&& other) noexcept;
  packaged_task& operator=(packaged_task&& other) noexcept;

  void swap(packaged_task& other) noexcept;

  bool valid() const noexcept;
  // result retrieval
   future<R> get_future();

  // execution
  void operator()(ArgTypes... );
  void make_ready_at_thread_exit(ArgTypes...);

  void reset();
  template<typename F>
  void set_wait_callback(F f);  // EXTENSION
};
```

### Task Constructor

```
packaged_task(R(*f)(ArgTypes...));

template<typename F>
packaged_task(F&&f);
```

Preconditions: `f()` is a valid expression with a return type convertible to `R`. Invoking a copy of `f` must behave the same as invoking `f`.

Effects: Constructs a new `boost::packaged_task` with `boost::forward<F>(f)` stored as the associated task.

Throws: - Any exceptions thrown by the copy (or move) constructor of `f`.

- `std::bad_alloc` if memory for the internal data structures could not be allocated.

Notes: The R(*f)(ArgTypes...)) overload to allow passing a function without needing to use `&`.

Remark: This constructor doesn't participate in overload resolution if decay<F>::type is the same type as boost::packaged_task<R>.

### Allocator Constructor

```
template <class Allocator>
packaged_task(allocator_arg_t, Allocator a, R(*f)(ArgTypes...));
template <class F, class Allocator>
packaged_task(allocator_arg_t, Allocator a, F&& f);
```

Preconditions: `f()` is a valid expression with a return type convertible to `R`. Invoking a copy of `f` shall behave the same as invoking `f`.

Effects: Constructs a new `boost::packaged_task` with `boost::forward<F>(f)` stored as the associated task using the allocator `a`.

Throws: Any exceptions thrown by the copy (or move) constructor of `f`. `std::bad_alloc` if memory for the internal data structures could not be allocated.

Notes: Available only if BOOST_THREAD_FUTURE_USES_ALLOCATORS is defined.

Notes: The R(*f)(ArgTypes...)) overload to allow passing a function without needing to use `&`.

### Move Constructor

```
packaged_task(packaged_task && other);
```

Effects: Constructs a new `boost::packaged_task`, and transfers ownership of the task associated with `other` to `*this`, leaving `other` with no associated task.

Throws: Nothing.

Notes: If the compiler does not support rvalue-references, this is implemented using the boost.thread move emulation.

### Move Assignment Operator

```
packaged_task& operator=(packaged_task && other);
```

Effects: Transfers ownership of the task associated with `other` to `*this`, leaving `other` with no associated task. If there was already a task associated with `*this`, and that task has not been invoked, sets any futures associated with that task to *ready* with a `boost::broken_promise` exception as the result.

Throws: Nothing.

Notes: If the compiler does not support rvalue-references, this is implemented using the boost.thread move emulation.

### Destructor

```
~packaged_task();
```

Effects: Destroys `*this`. If there was a task associated with `*this`, and that task has not been invoked, sets any futures associated with that task to *ready* with a `boost::broken_promise` exception as the result.

Throws: Nothing.

### Member Function `get_future()`

```
future<R> get_future();
```

Effects: Returns a `future` associated with the result of the task associated with `*this`.

Throws: `boost::task_moved` if ownership of the task associated with `*this` has been moved to another instance of `boost::packaged_task`. `boost::future_already_retrieved` if the future associated with the task has already been retrieved.

### Member Function `operator()()`

```
void operator()();
```

Effects: Invoke the task associated with `*this` and store the result in the corresponding future. If the task returns normally, the return value is stored as the asynchronous result, otherwise the exception thrown is stored. Any threads blocked waiting for the asynchronous result associated with this task are woken.

Postconditions: All futures waiting on the asynchronous result are *ready*

Throws: - `boost::task_moved` if ownership of the task associated with `*this` has been moved to another instance of `boost::packaged_task`.

- `boost::task_already_started` if the task has already been invoked.

### Member Function `make_ready_at_thread_exit()`

```
void make_ready_at_thread_exit(ArgTypes...);
```

Effects: Invoke the task associated with `*this` and store the result in the corresponding future. If the task returns normally, the return value is stored as the asynchronous result, otherwise the exception thrown is stored. In either case, this is done without making that state ready immediately. Schedules the shared state to be made ready when the current thread exits, after all objects of thread storage duration associated with the current thread have been destroyed.

Throws: - `boost::task_moved` if ownership of the task associated with `*this` has been moved to another instance of `boost::packaged_task`.

- `boost::task_already_started` if the task has already been invoked.

### Member Function `reset()`

```
void reset();
```

Effects: Reset the state of the packaged_task so that it can be called again.

Throws: `boost::task_moved` if ownership of the task associated with `*this` has been moved to another instance of `boost::packaged_task`.

### Member Function `set_wait_callback()` EXTENSION

```
template<typename F>
void set_wait_callback(F f);
```

Preconditions: The expression `f(t)` where `t` is a lvalue of type `boost::packaged_task` shall be well-formed. Invoking a copy of `f` shall have the same effect as invoking `f`

Effects: Store a copy of `f` with the task associated with `*this` as a *wait callback*. This will replace any existing wait callback store alongside that task. If a thread subsequently calls one of the wait functions on a `future` or `boost::shared_future` associated with this task, and the result of the task is not *ready*, `f(*this)` shall be invoked.

Throws: `boost::task_moved` if ownership of the task associated with `*this` has been moved to another instance of `boost::packaged_task`.

## Non-member function `decay_copy()`

```
template <class T>
typename decay<T>::type decay_copy(T&& v)
{
  return boost::forward<T>(v);
}
```

## Non-member function `async()`

```
template <class F>
 future<typename result_of<typename decay<F>::type()>::type>
async(F&& f);
template <class F>
 future<typename result_of<typename decay<F>::type()>::type>
async(launch policy, F&& f);

template <class F, class... Args>
 future<typename result_of<typename decay<F>::type(typename decay<Args>::type...)>::type>
async(F&& f, Args&&... args);
template <class F, class... Args>
 future<typename result_of<typename decay<F>::type(typename decay<Args>::type...)>::type>
async(launch policy, F&& f, Args&&... args);
```

The function template async provides a mechanism to launch a function potentially in a new thread and provides the result of the function in a future object with which it shares a shared state.

> **Warning**
>
> `async(launch::deferred, F)` is NOT YET IMPLEMENTED!

> **Warning**
>
> the variadic prototype is provided only on C++11 compilers supporting rvalue references, variadic templates, decltype and a standard library providing <tuple>, and BOOST_THREAD_PROVIDES_SIGNATURE_PACKAGED_TASK is defined.

### Non-Variadic variant

Requires:

```
decay_copy(boost::forward<F>(f))()
```

shall be a valid expression.

Effects: The first function behaves the same as a call to the second function with a policy argument of `launch::async | launch::deferred` and the same arguments for `F`. The second function creates a shared state that is associated with the returned future object.

The further behavior of the second function depends on the policy argument as follows (if more than one of these conditions applies, the implementation may choose any of the corresponding policies):

- if `policy & launch::async` is non-zero - calls `decay_copy(boost::forward<F>(f))()` as if in a new thread of execution represented by a thread object with the calls to `decay_copy()` being evaluated in the thread that called `async`. Any return value is stored as the result in the shared state. Any exception propagated from the execution of `decay_copy(boost::forward<F>(f))()` is stored as the exceptional result in the shared state. The thread object is stored in the shared state and affects the behavior of any asynchronous return objects that reference that state.

- if `policy & launch::deferred` is non-zero - Stores `decay_copy(boost::forward<F>(f))` in the shared state. This copy of `f` constitute a deferred function. Invocation of the deferred function evaluates `boost::move(g)()` where `g` is the stored value of `decay_copy(boost::forward<F>(f))`. The shared state is not made ready until the function has completed. The first call to a non-timed waiting function on an asynchronous return object referring to this shared state shall invoke the deferred function in the thread that called the waiting function. Once evaluation of `boost::move(g)()` begins, the function is no longer considered deferred. (Note: If this policy is specified together with other policies, such as when using a policy value of `launch::async | launch::deferred`, implementations should defer invocation or the selection of the policy when no more concurrency can be effectively exploited.)

Returns: An object of type `future<typename result_of<typename decay<F>::type()>::type>` that refers to the shared state created by this call to `async`.

Synchronization: Regardless of the provided policy argument,

- the invocation of `async` synchronizes with the invocation of `f`. (Note: This statement applies even when the corresponding future object is moved to another thread.); and

- the completion of the function `f` is sequenced before the shared state is made ready. (Note: `f` might not be called at all, so its completion might never happen.)

If the implementation chooses the `launch::async` policy,

- a call to a non-timed waiting function on an asynchronous return object that shares the shared state created by this async call shall block until the associated thread has completed, as if joined;

- the associated thread completion synchronizes with the return from the first function that successfully detects the ready status of the shared state or with the return from the last function that releases the shared state, whichever happens first.

Throws: `system_error` if policy is `launch::async` and the implementation is unable to start a new thread.

Error conditions: - `resource_unavailable_try_again` - if policy is `launch::async` and the system is unable to start a new thread.

Remarks: The first signature shall not participate in overload resolution if decay<F>::type is boost::launch.

### Variadic variant

Requires: `F` and each `Ti` in `Args` shall satisfy the `MoveConstructible` requirements.

invoke (decay_copy (boost::forward<F>(f)), decay_copy (boost::forward<Args>(args))...)

shall be a valid expression.

Effects: - The first function behaves the same as a call to the second function with a policy argument of `launch::async | launch::deferred` and the same arguments for `F` and `Args`.

- The second function creates a shared state that is associated with the returned future object. The further behavior of the second function depends on the policy argument as follows (if more than one of these conditions applies, the implementation may choose any of the corresponding policies):

- if policy & launch::async is non-zero - calls invoke(decay_copy(forward<F>(f)), decay_copy (forward<Args>(args))...) as if in a new thread of execution represented by a thread object with the calls to decay_copy() being evaluated in the thread that called async. Any return value is stored as the result in the shared state. Any exception propagated from the execution of invoke(decay_copy(boost::forward<F>(f)), decay_copy (boost::forward<Args>(args))...) is stored as the exceptional result in the shared state. The thread object is stored in the shared state and affects the behavior of any asynchronous return objects that reference that state.

- if policy & launch::deferred is non-zero - Stores decay_copy(forward<F>(f)) and decay_copy(forward<Args>(args))... in the shared state. These copies of f and args constitute a deferred function. Invocation of the deferred function evaluates invoke(move(g), move(xyz)) where g is the stored value of decay_copy(forward<F>(f)) and xyz is the stored copy of decay_copy(forward<Args>(args)).... The shared state is not made ready until the function has completed. The first call to a non-timed waiting function on an asynchronous return object referring to this shared state shall invoke the deferred function in the thread that called the waiting function. Once evaluation of invoke(move(g), move(xyz)) begins, the function is no longer considered deferred.

Note: If this policy is specified together with other policies, such as when using a policy value of launch::async | launch::deferred, implementations should defer invocation or the selection of the policy when no more concurrency can be effectively exploited.

Returns: An object of type future<typename result_of<typename decay<F>::type(typename decay<Args>::type...)>::type> that refers to the shared state created by this call to async.

Synchronization: Regardless of the provided policy argument,

- the invocation of async synchronizes with the invocation of f. (Note: This statement applies even when the corresponding future object is moved to another thread.); and

- the completion of the function f is sequenced before the shared state is made ready. (Note: f might not be called at all, so its completion might never happen.) If the implementation chooses the launch::async policy,

- a call to a waiting function on an asynchronous return object that shares the shared state created by this async call shall block until the associated thread has completed, as if joined;

- the associated thread completion synchronizes with the return from the first function that successfully detects the ready status of the shared state or with the return from the last function that releases the shared state, whichever happens first.

Throws: system_error if policy is launch::async and the implementation is unable to start a new thread.

Error conditions: - resource_unavailable_try_again - if policy is launch::async and the system is unable to start a new thread.

Remarks: The first signature shall not participate in overload resolution if decay<F>::type is boost::launch.

## Non-member function `wait_for_any()`

```
template<typename Iterator>
Iterator wait_for_any(Iterator begin,Iterator end);

template<typename F1,typename F2>
unsigned wait_for_any(F1& f1,F2& f2);

template<typename F1,typename F2,typename F3>
unsigned wait_for_any(F1& f1,F2& f2,F3& f3);

template<typename F1,typename F2,typename F3,typename F4>
unsigned wait_for_any(F1& f1,F2& f2,F3& f3,F4& f4);

template<typename F1,typename F2,typename F3,typename F4,typename F5>
unsigned wait_for_any(F1& f1,F2& f2,F3& f3,F4& f4,F5& f5);
```

Preconditions: The types `Fn` shall be specializations of `future` or `boost::shared_future`, and `Iterator` shall be a forward iterator with a `value_type` which is a specialization of `future` or `boost::shared_future`.

Effects: Waits until at least one of the specified futures is *ready*.

Returns: The range-based overload returns an `Iterator` identifying the first future in the range that was detected as *ready*. The remaining overloads return the zero-based index of the first future that was detected as *ready* (first parameter => 0, second parameter => 1, etc.).

Throws: `boost::thread_interrupted` if the current thread is interrupted. Any exception thrown by the *wait callback* associated with any of the futures being waited for. `std::bad_alloc` if memory could not be allocated for the internal wait structures.

Notes: `wait_for_any()` is an *interruption point*.

## Non-member function `wait_for_all()`

```
template<typename Iterator>
void wait_for_all(Iterator begin,Iterator end);

template<typename F1,typename F2>
void wait_for_all(F1& f1,F2& f2);

template<typename F1,typename F2,typename F3>
void wait_for_all(F1& f1,F2& f2,F3& f3);

template<typename F1,typename F2,typename F3,typename F4>
void wait_for_all(F1& f1,F2& f2,F3& f3,F4& f4);

template<typename F1,typename F2,typename F3,typename F4,typename F5>
void wait_for_all(F1& f1,F2& f2,F3& f3,F4& f4,F5& f5);
```

Preconditions: The types `Fn` shall be specializations of `future` or `boost::shared_future`, and `Iterator` shall be a forward iterator with a `value_type` which is a specialization of `future` or `boost::shared_future`.

Effects: Waits until all of the specified futures are *ready*.

Throws: Any exceptions thrown by a call to `wait()` on the specified futures.

Notes: `wait_for_all()` is an *interruption point*.

## Non-member function `make_future()`

```
template <typename T>
future<typename decay<T>::type> make_future(T&& value);  // EXTENSION
future<void> make_future();  // EXTENSION
```

Effects: The value that is passed in to the function is moved to the shared state of the returned function if it is an rvalue. Otherwise the value is copied to the shared state of the returned function. .

Returns: - future<T>, if function is given a value of type T

- future<void>, if the function is not given any inputs.

Postcondition: - Returned future<T>, valid() == true

- Returned future<T>, is_ready() = true

## Non-member function `make_shared_future()`

```
template <typename T>
shared_future<typename decay<T>::type> make_shared_future(T&& value);  // EXTENSION
shared_future<void> make_shared_future();  // EXTENSION
```

Effects: The value that is passed in to the function is moved to the shared state of the returned function if it is an rvalue. Otherwise the value is copied to the shared state of the returned function. .

Returns: - shared_future<T>, if function is given a value of type T

- shared_future<void>, if the function is not given any inputs.

Postcondition: - Returned shared_future<T>, valid() == true

- Returned shared_future<T>, is_ready() = true

# Thread Local Storage

## Synopsis

Thread local storage allows multi-threaded applications to have a separate instance of a given data item for each thread. Where a single-threaded application would use static or global data, this could lead to contention, deadlock or data corruption in a multi-threaded application. One example is the C `errno` variable, used for storing the error code related to functions from the Standard C library. It is common practice (and required by POSIX) for compilers that support multi-threaded applications to provide a separate instance of `errno` for each thread, in order to avoid different threads competing to read or update the value.

Though compilers often provide this facility in the form of extensions to the declaration syntax (such as `__declspec(thread)` or `thread` annotations on `static` or namespace-scope variable declarations), such support is non-portable, and is often limited in some way, such as only supporting POD types.

## Portable thread-local storage with `boost::thread_specific_ptr`

`boost::thread_specific_ptr` provides a portable mechanism for thread-local storage that works on all compilers supported by **Boost.Thread**. Each instance of `boost::thread_specific_ptr` represents a pointer to an object (such as `errno`) where each thread must have a distinct value. The value for the current thread can be obtained using the `get()` member function, or by using the `*` and `->` pointer deference operators. Initially the pointer has a value of `NULL` in each thread, but the value for the current thread can be set using the `reset()` member function.

If the value of the pointer for the current thread is changed using `reset()`, then the previous value is destroyed by calling the cleanup routine. Alternatively, the stored value can be reset to `NULL` and the prior value returned by calling the `release()` member function, allowing the application to take back responsibility for destroying the object.

## Cleanup at thread exit

When a thread exits, the objects associated with each `boost::thread_specific_ptr` instance are destroyed. By default, the object pointed to by a pointer `p` is destroyed by invoking `delete p`, but this can be overridden for a specific instance of `boost::thread_specific_ptr` by providing a cleanup routine to the constructor. In this case, the object is destroyed by invoking `func(p)` where `func` is the cleanup routine supplied to the constructor. The cleanup functions are called in an unspecified order. If a cleanup routine sets the value of associated with an instance of `boost::thread_specific_ptr` that has already been cleaned up, that value is added to the cleanup list. Cleanup finishes when there are no outstanding instances of `boost::thread_specific_ptr` with values.

Note: on some platforms, cleanup of thread-specific data is not performed for threads created with the platform's native API. On those platforms such cleanup is only done for threads that are started with `boost::thread` unless `boost::on_thread_exit()` is called manually from that thread.

## Rationale about the nature of the key

Boost.Thread uses the address of the `thread_specific_ptr` instance as key of the thread specific pointers. This avoids to create/destroy a key which will need a lock to protect from race conditions. This has a little performance liability, as the access must be done using an associative container.

# Class `thread_specific_ptr`

```
//  #include <boost/thread/tss.hpp>

namespace boost
{
  template <typename T>
  class thread_specific_ptr
  {
  public:
      thread_specific_ptr();
      explicit thread_specific_ptr(void (*cleanup_function)(T*));
      ~thread_specific_ptr();

      T* get() const;
      T* operator->() const;
      T& operator*() const;

      T* release();
      void reset(T* new_value=0);
  };
}
```

### `thread_specific_ptr();`

Requires: `delete this->get()` is well-formed.

Effects: Construct a `thread_specific_ptr` object for storing a pointer to an object of type `T` specific to each thread. The default `delete`-based cleanup function will be used to destroy any thread-local objects when `reset()` is called, or the thread exits.

Throws: `boost::thread_resource_error` if an error occurs.

### `explicit thread_specific_ptr(void (*cleanup_function)(T*));`

Requires: `cleanup_function(this->get())` does not throw any exceptions.

Effects: Construct a `thread_specific_ptr` object for storing a pointer to an object of type `T` specific to each thread. The supplied `cleanup_function` will be used to destroy any thread-local objects when `reset()` is called, or the thread exits.

Throws: `boost::thread_resource_error` if an error occurs.

### `~thread_specific_ptr();`

Requires: All the thread specific instances associated to this thread_specific_ptr (except maybe the one associated to this thread) must be null.

Effects: Calls `this->reset()` to clean up the associated value for the current thread, and destroys `*this`.

Throws: Nothing.

Remarks: The requirement is due to the fact that in order to delete all these instances, the implementation should be forced to maintain a list of all the threads having an associated specific ptr, which is against the goal of thread specific data.

> **Note**
>
> Care needs to be taken to ensure that any threads still running after an instance of `boost::thread_specific_ptr` has been destroyed do not call any member functions on that instance.

**`T* get() const;`**

Returns: The pointer associated with the current thread.

Throws: Nothing.

> **Note**
>
> The initial value associated with an instance of `boost::thread_specific_ptr` is `NULL` for each thread.

**`T* operator->() const;`**

Returns: `this->get()`

Throws: Nothing.

**`T& operator*() const;`**

Requires: `this->get` is not `NULL`.

Returns: `*(this->get())`

Throws: Nothing.

**`void reset(T* new_value=0);`**

Effects: If `this->get()!=new_value` and `this->get()` is non-`NULL`, invoke `delete this->get()` or `cleanup_function(this->get())` as appropriate. Store `new_value` as the pointer associated with the current thread.

Postcondition: `this->get()==new_value`

Throws: `boost::thread_resource_error` if an error occurs.

**`T* release();`**

Effects: Return `this->get()` and store `NULL` as the pointer associated with the current thread without invoking the cleanup function.

Postcondition: `this->get()==0`

Throws: Nothing.

# Time Requirements

As of Boost 1.50.0, the **Boost.Thread** library uses Boost.Chrono library for all operations that require a time out as defined in the standard c++11. These include (but are not limited to):

- `boost::this_thread::sleep_for`
- `boost::this_thread::sleep_until`
- `boost::thread::try_join_for`
- `boost::thread::try_join_until`
- `boost::condition_variable::wait_for`
- `boost::condition_variable::wait_until`
- `boost::condition_variable_any::wait_for`
- `boost::condition_variable_any::wait_until`
- `TimedLockable::try_lock_for`
- `TimedLockable::try_lock_until`

# Deprecated

The time related functions introduced in Boost 1.35.0, using the Boost.Date_Time library are deprecated. These include (but are not limited to):

- `boost::this_thread::sleep()`
- `timed_join()`
- `timed_wait()`
- `timed_lock()`

For the overloads that accept an absolute time parameter, an object of type `boost::system_time` is required. Typically, this will be obtained by adding a duration to the current time, obtained with a call to `boost::get_system_time()`. e.g.

```
boost::system_time const timeout=boost::get_system_time() + boost::posix_time::milliseconds(500);

extern bool done;
extern boost::mutex m;
extern boost::condition_variable cond;

boost::unique_lock<boost::mutex> lk(m);
while(!done)
{
    if(!cond.timed_wait(lk,timeout))
    {
        throw "timed out";
    }
}
```

For the overloads that accept a *TimeDuration* parameter, an object of any type that meets the Boost.Date_Time Time Duration requirements can be used, e.g.

```
boost::this_thread::sleep(boost::posix_time::milliseconds(25));

boost::mutex m;
if(m.timed_lock(boost::posix_time::nanoseconds(100)))
{
    //  ...
}
```

## Typedef `system_time`

```
#include <boost/thread/thread_time.hpp>

typedef boost::posix_time::ptime system_time;
```

See the documentation for `boost::posix_time::ptime` in the Boost.Date_Time library.

## Non-member function `get_system_time()`

```
#include <boost/thread/thread_time.hpp>

system_time get_system_time();
```

Returns: The current time.

Throws: Nothing.

# Emulations

## `=delete` emulation

C++11 allows to delete some implicitly generated functions as constructors and assignment using '= delete' as in

```
public:
  thread(thread const&) = delete;
```

On compilers not supporting this feature, Boost.Thread relays on a partial simulation, it declares the function as private without definition.

```
private:
  thread(thread &);
```

The emulation is partial as the private function can be used for overload resolution for some compilers and prefer it to other overloads that need a conversion. See below the consequences on the move semantic emulation.

## Move semantics

In order to implement Movable classes, move parameters and return types Boost.Thread uses the rvalue reference when the compiler support it. On compilers not supporting it Boost.Thread uses either the emulation provided by Boost.Move or the emulation provided by the previous versions of Boost.Thread depending whether `BOOST_THREAD_USES_MOVE` is defined or not. This macros is unset by default when `BOOST_THREAD_VERSION` is 2. Since `BOOST_THREAD_VERSION` 3, `BOOST_THREAD_USES_MOVE` is defined.

### Deprecated Version 2 interface

Previous to version 1.50, Boost.Thread make use of its own move semantic emulation which had more limitations than the provided by Boost.Move. In addition, it is of interest of the whole Boost community that Boost.Thread uses Boost.Move so that boost::thread can be stored on Movable aware containers.

To preserve backward compatibility at least during some releases, Boost.Thread allows the user to use the deprecated move semantic emulation defining BOOST_THREAD_DONT_USE_MOVE.

Many aspects of move semantics can be emulated for compilers not supporting rvalue references and Boost.Thread legacy offers tools for that purpose.

#### Helpers class and function

Next follows the interface of the legacy move semantic helper class and function.

```
namespace boost
{
  namespace detail
  {
      template<typename T>
      struct thread_move_t
      {
        explicit thread_move_t(T& t_);
        T& operator*() const;
        T* operator->() const;
      private:
        void operator=(thread_move_t&);
      };
  }
  template<typename T>
  boost::detail::thread_move_t<T> move(boost::detail::thread_move_t<T> t);
}
```

## Movable emulation

We can write a MovableOny class as follows. You just need to follow these simple steps:

- Add a conversion to the `detail::thread_move_t<classname>`
- Make the copy constructor private.
- Write a constructor taking the parameter as `detail::thread_move_t<classname>`
- Write an assignment taking the parameter as `detail::thread_move_t<classname>`

For example the thread class defines the following:

```
class thread
{
  // ...
private:
    thread(thread&);
    thread& operator=(thread&);
public:
    detail::thread_move_t<thread> move()
    {
        detail::thread_move_t<thread> x(*this);
        return x;
    }
    operator detail::thread_move_t<thread>()
    {
        return move();
    }
    thread(detail::thread_move_t<thread> x)
    {
        thread_info=x->thread_info;
        x->thread_info.reset();
    }
    thread& operator=(detail::thread_move_t<thread> x)
    {
        thread new_thread(x);
        swap(new_thread);
        return *this;
    }
  // ...

};
```

## Portable interface

In order to make the library code portable Boost.Thread uses some macros that will use either the ones provided by Boost.Move or the deprecated move semantics provided by previous versions of Boost.Thread.

See the Boost.Move documentation for a complete description on how to declare new Movable classes and its limitations.

- `BOOST_THREAD_RV_REF(TYPE)` is the equivalent of `BOOST_RV_REF(TYPE)`
- `BOOST_THREAD_RV_REF_BEG` is the equivalent of `BOOST_RV_REF_BEG(TYPE)`
- `BOOST_THREAD_RV_REF_END` is the equivalent of `BOOST_RV_REF_END(TYPE)`
- `BOOST_THREAD_FWD_REF(TYPE)` is the equivalent of `BOOST_FWD_REF(TYPE)

In addition the following macros are needed to make the code portable:

- `BOOST_THREAD_RV(V)` macro to access the rvalue from a BOOST_THREAD_RV_REF(TYPE),
- `BOOST_THREAD_MAKE_RV_REF(RVALUE)` makes a rvalue.
- `BOOST_THREAD_DCL_MOVABLE(CLASS)` to avoid conflicts with Boost.Move
- `BOOST_THREAD_DCL_MOVABLE_BEG(T1)` and `BOOST_THREAD_DCL_MOVABLE_END` are variant of `BOOST_THREAD_DCL_MOVABLE` when the parameter is a template instantiation.

Other macros are provided and must be included on the public section:

- `BOOST_THREAD_NO_COPYABLE` declares a class no-copyable either deleting the copy constructors and copy assignment or moving them to the private section.

- BOOST_THREAD_MOVABLE(CLASS) declares all the implicit conversions to an rvalue-reference.
- BOOST_THREAD_MOVABLE_ONLY(CLASS) is the equivalent of BOOST_MOVABLE_BUT_NOT_COPYABLE(CLASS)
- BOOST_THREAD_COPYABLE_AND_MOVABLE(CLASS) is the equivalent of BOOST_COPYABLE_AND_MOVABLE(CLASS)

#### BOOST_THREAD_NO_COPYABLE(CLASS)

This macro marks a class as no copyable, disabling copy construction and assignment.

#### BOOST_THREAD_MOVABLE(CLASS)

This macro marks a class as movable, declaring all the implicit conversions to an rvalue-reference.

#### BOOST_THREAD_MOVABLE_ONLY(CLASS)

This macro marks a type as movable but not copyable, disabling copy construction and assignment. The user will need to write a move constructor/assignment to fully write a movable but not copyable class.

#### BOOST_THREAD_COPYABLE_AND_MOVABLE(CLASS)

This macro marks a type as copyable and movable. The user will need to write a move constructor/assignment and a copy assignment to fully write a copyable and movable class.

#### BOOST_THREAD_RV_REF(TYPE), BOOST_THREAD_RV_REF_BEG and BOOST_THREAD_RV_REF_END

This macro is used to achieve portable syntax in move constructors and assignments for classes marked as BOOST_THREAD_COPYABLE_AND_MOVABLE or BOOST_THREAD_MOVABLE_ONLY.

BOOST_THREAD_RV_REF_BEG and BOOST_THREAD_RV_REF_END are used when the parameter end with a > to avoid the compiler error.

#### BOOST_THREAD_RV(V)

While Boost.Move emulation allows to access an rvalue reference BOOST_THREAD_RV_REF(TYPE) using the dot operator, the legacy defines the operator->. We need then a macro BOOST_THREAD_RV that mask this difference. E.g.

```
thread(BOOST_THREAD_RV_REF(thread) x)
{
    thread_info=BOOST_THREAD_RV(x).thread_info;
    BOOST_THREAD_RV(x).thread_info.reset();
}
```

The use of this macros has reduced considerably the size of the Boost.Thread move related code.

#### BOOST_THREAD_MAKE_RV_REF(RVALUE)

While Boost.Move is the best C++03 move emulation there are some limitations that impact the way the library can be used. For example, with the following declarations

```
class thread {
  // ...
private:
  thread(thread &);
public:
  thread(rv<thread>&);
  // ...
};
```

This could not work on some compilers even if thread is convertible to `rv<thread>` because the compiler prefers the private copy constructor.

```
thread mkth()
{
  return thread(f);
}
```

On these compilers we need to use instead an explicit conversion. The library provides a move member function that allows to workaround the issue.

```
thread mkth()
{
  return thread(f).move();
}
```

Note that `::boost::move` can not be used in this case as thread is not implicitly convertible to `thread&`.

```
thread mkth()
{
  return ::boost::move(thread(f));
}
```

To make the code portable Boost.Thread the user needs to use a macro `BOOST_THREAD_MAKE_RV_REF` that can be used as in

```
thread mkth()
{
  return BOOST_THREAD_MAKE_RV_REF(thread(f));
}
```

Note that this limitation is shared also by the legacy Boost.Thread move emulation.

#### `BOOST_THREAD_DCL_MOVABLE`, `BOOST_THREAD_DCL_MOVABLE_BEG(T1)` and `BOOST_THREAD_DCL_MOVABLE_END`

As Boost.Move defines also the `boost::move` function we need to specialize the `has_move_emulation_enabled_aux` metafunction.

```
template <>
struct has_move_emulation_enabled_aux<thread>
  : BOOST_MOVE_BOOST_NS::integral_constant<bool, true>
{};
```

so that the following Boost.Move overload is disabled

```
template <class T>
inline typename BOOST_MOVE_BOOST_NS::disable_if<has_move_emulation_en↲
abled_aux<T>, T&>::type move(T& x);
```

The macros `BOOST_THREAD_DCL_MOVABLE(CLASS)`, `BOOST_THREAD_DCL_MOVABLE_BEG(T1)` and `BOOST_THREAD_DCL_MOVABLE_END` are used for this purpose. E.g.

```
BOOST_THREAD_DCL_MOVABLE(thread)
```

and

```
BOOST_THREAD_DCL_MOVABLE_BEG(T) promise<T> BOOST_THREAD_DCL_MOVABLE_END
```

# Bool explicit conversion

Locks provide an explicit bool conversion operator when the compiler provides them.

```
explicit operator bool() const;
```

The library provides un implicit conversion to an undefined type that can be used as a conditional expression.

```
#if defined(BOOST_NO_EXPLICIT_CONVERSION_OPERATORS)
    operator unspecified-bool-type() const;
    bool operator!() const;
#else
    explicit operator bool() const;
#endif
```

The user should use the lock.owns_lock() when a explicit conversion is required.

### `operator` *unspecified-bool-type*`() const`

Returns: If `owns_lock()` would return `true`, a value that evaluates to `true` in boolean contexts, otherwise a value that evaluates to `false` in boolean contexts.

Throws: Nothing.

### `bool operator!() const`

Returns: `! owns_lock()`.

Throws: Nothing.

# Scoped Enums

Some of the enumerations defined in the standard library are scoped enums.

On compilers that don't support them, the library uses a class to wrap the underlying type. Instead of

```
enum class future_errc
{
    broken_promise,
    future_already_retrieved,
    promise_already_satisfied,
    no_state
};
```

the library declare these types as

```
BOOST_SCOPED_ENUM_DECLARE_BEGIN(future_errc)
{
    broken_promise,
    future_already_retrieved,
    promise_already_satisfied,
    no_state
}
BOOST_SCOPED_ENUM_DECLARE_END(future_errc)
```

These macros allows to use 'future_errc' in almost all the cases as an scoped enum.

There are however some limitations:

- The type is not a C++ enum, so 'is_enum<future_errc>' will be false_type.
- The emulated scoped enum can not be used in switch nor in template arguments. For these cases the user needs to use some macros.

Instead of

```
       switch (ev)
       {
       case future_errc::broken_promise:
// ...
```

use

```
switch (boost::native_value(ev))
{
case future_errc::broken_promise:
```

And instead of

```
#ifdef BOOST_NO_SCOPED_ENUMS
template <>
struct BOOST_SYMBOL_VISIBLE is_error_code_enum<future_errc> : public true_type { };
#endif
```

use

```
#ifdef BOOST_NO_SCOPED_ENUMS
template <>
struct BOOST_SYMBOL_VISIBLE is_error_code_enum<future_errc::enum_type> : public true_type { };
#endif
```

# Acknowledgments

The original implementation of **Boost.Thread** was written by William Kempf, with contributions from numerous others. This new version initially grew out of an attempt to rewrite **Boost.Thread** to William Kempf's design with fresh code that could be released under the Boost Software License. However, as the C++ Standards committee have been actively discussing standardizing a thread library for C++, this library has evolved to reflect the proposals, whilst retaining as much backwards-compatibility as possible.

Particular thanks must be given to Roland Schwarz, who contributed a lot of time and code to the original **Boost.Thread** library, and who has been actively involved with the rewrite. The scheme for dividing the platform-specific implementations into separate directories was devised by Roland, and his input has contributed greatly to improving the quality of the current implementation.

Thanks also must go to Peter Dimov, Howard Hinnant, Alexander Terekhov, Chris Thomasson and others for their comments on the implementation details of the code.

# Conformance and Extension

## C++11 standard Thread library

**Table 2. C++11 standard Conformance**

| Section | Description | Status | Comments | Ticket |
|---|---|---|---|---|
| 30 | Thread support library | Partial | - | - |
| 30.1 | General | - | - | - |
| 30.2 | Requirements | - | - | - |
| 30.2.1 | Template parameter names | - | - | - |
| 30.2.2 | Exceptions | Yes | - | - |
| 30.2.3 | Native handles | Yes | - | - |
| 30.2.4 | Timing specifications | Yes | - | - |
| 30.2.5 | Requirements for Lockable types | Yes | - | - |
| 30.2.5.1 | In general | - | - | - |
| 30.2.5.2 | BasicLockable requirements | Yes | - | - |
| 30.2.5.3 | Lockable requirements | yes | - | - |
| 30.2.5.4 | TimedLockable requirements | Yes | - | - |
| 30.2.6 | decay_copy | - | - | - |
| 30.3 | Threads | Yes | - | - |
| 30.3.1 | Class thread | Yes | - | - |
| 30.3.1.1 | Class thread::id | Yes | - | - |
| 30.3.1.2 | thread constructors | Partial | - | - |
| 30.3.1.3 | thread destructor | Yes | - | - |
| 30.3.1.4 | thread assignment | Yes | - | - |
| 30.3.1.5 | thread members | Yes | - | - |
| 30.3.1.6 | thread static members | Yes | - | - |
| 30.3.1.7 | thread specialized algorithms | Yes | - | - |
| 30.3.2 | Namespace this_thread | Yes | - | - |
| 30.4 | Mutual exclusion | Partial | - | - |
| 30.4.1 | Mutex requirements | Yes | - | - |

| Section | Description | Status | Comments | Ticket |
|---|---|---|---|---|
| 30.4.1.1 | In general | Yes | - | - |
| 30.4.1.2 | Mutex types | Yes | - | - |
| 30.4.1.2.1 | Class mutex | Yes | - | - |
| 30.4.1.2.2 | Class recursive_mutex | Yes | - | - |
| 30.4.1.3 | Timed mutex types | Yes | - | - |
| 30.4.1.3.1 | Class timed_mutex | Yes | - | - |
| 30.4.1.3.1 | Class recursive_timed_mutex | Yes | - | - |
| 30.4.2 | Locks | Yes | - | - |
| 30.4.2.1 | Class template lock_guard | Yes | - | - |
| 30.4.2.2 | Class template unique_lock | Yes | - | - |
| 30.4.2.2.1 | unique_lock constructors, destructor, and assignment | Yes | - | - |
| 30.4.2.2.2 | unique_lock locking | Yes | - | - |
| 30.4.2.2.3 | unique_lock modifiers | Yes | - | - |
| 30.4.2.2.4 | unique_lock observers | Yes | | - |
| 30.4.3 | Generic locking algorithms | Partial | variadic | #6227 |
| 30.4.4 | Call once | Partial | call_once | #7285 |
| 30.4.4.1 | Struct once_flag | Yes | - | - |
| 30.4.4.2 | Function call_once | Partial | interface | #7285 |
| 30.5 | Condition variables | Yes | - | - |
| 30.5.1 | Class condition_variable | Yes | - | - |
| 30.5.2 | Class condition_variable_any | Yes | - | - |
| 30.6 | Futures | Partial | noexcept | #7279 |
| 30.6.1 | Overview | Partial | - | - |
| 30.6.2 | Error handling | Yes | - | - |

| Section | Description | Status | Comments | Ticket |
|---|---|---|---|---|
| 30.6.3 | Class future_error | Partial | noexcept | #7279 |
| 30.6.4 | Shared state | - | - | - |
| 30.6.5 | Class template promise | Yes | - | - |
| 30.6.6 | Class template future | Yes | - | - |
| 30.6.7 | Class template shared_future | Yes | - | - |
| 30.6.8 | Function template async | Yes | - | - |
| 30.6.9 | Class template packaged_task | Yes | - | - |

# Shared Locking extensions

### Table 3. Howard's Shared Locking Proposal Conformance

| Section | Description | Status | Comments |
|---|---|---|---|
| X | Shared Locking | Yes | Needs BOOST_THREAD_PROVIDES_SHARED_MUTEX_UPWARDS_CONVERSION |
| X.1 | Shared Lockables Concepts | Yes | - |
| X.1.1 | SharedLockable concept | Yes | - |
| X.1.2 | UpgradeLockable concept | Yes | - |
| X.2 | Shared Mutex Types | Yes | - |
| X.2.1 | shared_mutex class | Yes | - |
| X.2.2 | upgrade_mutex class | Yes | - |
| X.3 | Locks | Yes | - |
| X.3.1 | unique_lock class adaptations | Yes | - |
| X.3.2 | shared_lock class | Yes | - |
| X.3.3 | upgrade_lock class | Yes | - |