

primesieve

12.12

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Chapter 1

primesieve

1.1 About

primesieve is a C/C++ library for quickly generating prime numbers. It generates the primes below 10^9 in just 0.2 seconds on a single core of an Intel Core i7-6700 3.4GHz CPU from 2015. primesieve can generate primes and prime k-tuplets up to 2^{64} . primesieve's memory requirement is about $\pi(\sqrt{n}) * 8$ bytes per thread, its run-time complexity is $O(n \log \log n)$ operations. The recommended way to get started is to first have a look at a few C or C++ example programs. The most common use cases are iterating over primes using `next_prime()` or `prev_prime()` and storing primes in a vector or an array.

For more information please visit <https://github.com/kimwalisch/primesieve>.

1.2 Installation

- **Install libprimesieve using package manager.**
- **Build libprimesieve from source.**

1.3 C API

- `primesieve.h` - primesieve C header.
- `primesieve_iterator` - Provides the `primesieve_next_prime()` and `primesieve_prev_prime()` functions.
- **C examples** - Example programs that show how to use libprimesieve.
- **C error handling** - How to detect and handle errors.
- **Link against libprimesieve.**

1.4 C++ API

- `primesieve.hpp` - primesieve C++ header.
- `primesieve::iterator` - Provides the `next_prime()` and `prev_prime()` methods.
- **C++ examples** - Example programs that show how to use libprimesieve.
- **C++ error handling** - How to detect and handle errors.
- **Link against libprimesieve.**

1.5 Performance tips

- `libprimesieve` performance tips
- Multi-threading
- SIMD (vectorization)

Chapter 2

Hierarchical Index

2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

primesieve::iterator	9
primesieve_iterator	14
std::runtime_error	
primesieve::primesieve_error	13

Chapter 3

Class Index

3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

primesieve::iterator	Primesieve::iterator allows to easily iterate over primes both forwards and backwards	9
primesieve::primesieve_error	Primesieve throws a primesieve_error exception if an error occurs e.g	13
primesieve_iterator	C prime iterator, please refer to iterator.h for more information	14

Chapter 4

File Index

4.1 File List

Here is a list of all documented files with brief descriptions:

primesieve.h	
Primesieve C API	15
primesieve.hpp	
Primesieve C++ API	21
iterator.h	
Primesieve_iterator allows to easily iterate over primes both forwards and backwards	26
iterator.hpp	
Primesieve::iterator allows to easily iterate (forwards and backwards) over prime numbers	30
primesieve_error.hpp	
The primesieve_error class is used for all exceptions within primesieve	31

Chapter 5

Class Documentation

5.1 primesieve::iterator Struct Reference

`primesieve::iterator` allows to easily iterate over primes both forwards and backwards.

```
#include <iterator.hpp>
```

Public Member Functions

- `iterator ()` noexcept
Create a new iterator object.
- `iterator (uint64_t start, uint64_t stop_hint=std::numeric_limits< uint64_t >::max())` noexcept
Create a new iterator object.
- `void jump_to (uint64_t start, uint64_t stop_hint=std::numeric_limits< uint64_t >::max())` noexcept
Reset the primesieve iterator to start.
- `iterator (const iterator &)=delete`
`primesieve::iterator` objects cannot be copied.
- `iterator & operator= (const iterator &)=delete`
- `iterator (iterator &&) noexcept`
`primesieve::iterator` objects support move semantics.
- `iterator & operator= (iterator &&) noexcept`
- `~iterator ()`
Frees all memory.
- `void clear ()` noexcept
Reset the start number to 0 and free most memory.
- `void generate_next_primes ()`
Used internally by `next_prime()`.
- `void generate_prev_primes ()`
Used internally by `prev_prime()`.
- `uint64_t next_prime ()`
Get the next prime.
- `uint64_t prev_prime ()`
Get the previous prime.

Public Attributes

- `std::size_t i_`
Current index of the primes array.
- `std::size_t size_`
Current number of primes in the primes array.
- `uint64_t start_`
Generate primes $\geq$ start.
- `uint64_t stop_hint_`
Generate primes $\leq$ stop_hint.
- `uint64_t * primes_`
The primes array.
- `void * memory_`
Pointer to internal IteratorData data structure.

5.1.1 Detailed Description

`primesieve::iterator` allows to easily iterate over primes both forwards and backwards.

Generating the first prime has a complexity of $O(r \log \log r)$ operations with $r = n^{0.5}$, after that any additional prime is generated in amortized $O(\log n \log \log n)$ operations. The memory usage is $\text{PrimePi}(n^{0.5}) * 8$ bytes.

Examples

`prev_prime.cpp`, and `primesieve_iterator.cpp`.

5.1.2 Constructor & Destructor Documentation

5.1.2.1 `iterator()` [1/2]

```
primesieve::iterator::iterator ( ) [noexcept]
```

Create a new iterator object.

Generate primes ≥ 0 . The start number is default initialized to 0 and the stop_hint is default initialized `UINT64_MAX`.

5.1.2.2 `iterator()` [2/2]

```
primesieve::iterator::iterator (
    uint64_t start,
    uint64_t stop_hint = std::numeric_limits< uint64_t >::max() ) [noexcept]
```

Create a new iterator object.

Parameters

<i>start</i>	Generate primes $\geq$ start (or $\leq$ start).
<i>stop_hint</i>	Stop number optimization hint, gives significant speed up if few primes are generated. E.g. if you want to generate the primes ≤ 1000 use <code>stop_hint = 1000</code> .

5.1.3 Member Function Documentation

5.1.3.1 clear()

```
void primesieve::iterator::clear ( ) [noexcept]
```

Reset the start number to 0 and free most memory.

Keeps some smaller data structures in memory (e.g. the IteratorData object) that are useful if the [primesieve::iterator](#) is reused. The remaining memory uses at most 2 kilobytes.

5.1.3.2 generate_next_primes()

```
void primesieve::iterator::generate_next_primes ( )
```

Used internally by [next_prime\(\)](#).

[generate_next_primes\(\)](#) fills (overwrites) the primes array with the next few primes ($\sim 2^{10}$) that are larger than the current largest prime in the primes array or with the primes $\geq$ start if the primes array is empty. Note that this method also updates the i & size member variables of this [primesieve::iterator](#) struct. The size of the primes array varies, but it is > 0 and usually close to 2^{10} .

5.1.3.3 generate_prev_primes()

```
void primesieve::iterator::generate_prev_primes ( )
```

Used internally by [prev_prime\(\)](#).

[generate_prev_primes\(\)](#) fills (overwrites) the primes array with the next few primes $\sim O(\sqrt{n})$ that are smaller than the current smallest prime in the primes array or with the primes $\leq$ start if the primes array is empty. Note that this method also updates the i & size member variables of this [primesieve::iterator](#) struct. The size of the primes array varies, but it is > 0 and $\sim O(\sqrt{n})$.

5.1.3.4 jump_to()

```
void primesieve::iterator::jump_to (
    uint64_t start,
    uint64_t stop_hint = std::numeric_limits< uint64_t >::max() ) [noexcept]
```

Reset the primesieve iterator to start.

Parameters

<i>start</i>	Generate primes $\geq$ start (or $\leq$ start).
<i>stop_hint</i>	Stop number optimization hint, gives significant speed up if few primes are generated. E.g. if you want to generate the primes ≤ 1000 use stop_hint = 1000.

Examples

[prev_prime.cpp](#).

5.1.3.5 next_prime()

```
uint64_t primesieve::iterator::next_prime ( ) [inline]
```

Get the next prime.

Throws a [primesieve::primesieve_error](#) exception (derived from `std::runtime_error`) if any error occurs.

Examples

[primesieve_iterator.cpp](#).

5.1.3.6 prev_prime()

```
uint64_t primesieve::iterator::prev_prime ( ) [inline]
```

Get the previous prime.

`prev_prime(n)` returns 0 for $n \leq 2$. Note that [next_prime\(\)](#) runs up to 2x faster than [prev_prime\(\)](#). Hence if the same algorithm can be written using either [prev_prime\(\)](#) or [next_prime\(\)](#) it is preferable to use [next_prime\(\)](#).

Examples

[prev_prime.cpp](#).

5.1.4 Member Data Documentation

5.1.4.1 primes_

```
uint64_t* primesieve::iterator::primes_
```

The primes array.

The current smallest prime can be accessed using `primes[0]`. The current largest prime can be accessed using `primes[size-1]`.

The documentation for this struct was generated from the following file:

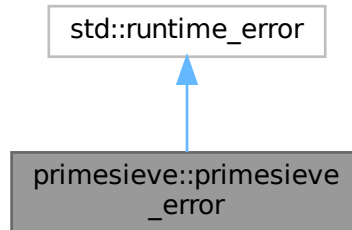
- [iterator.hpp](#)

5.2 primesieve::primesieve_error Class Reference

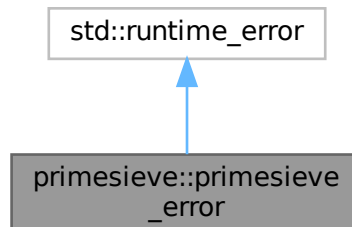
primesieve throws a [primesieve_error](#) exception if an error occurs e.g.

```
#include <primesieve_error.hpp>
```

Inheritance diagram for primesieve::primesieve_error:



Collaboration diagram for primesieve::primesieve_error:



Public Member Functions

- **primesieve_error** (const std::string &msg)

5.2.1 Detailed Description

primesieve throws a [primesieve_error](#) exception if an error occurs e.g.

prime > 2⁶⁴.

The documentation for this class was generated from the following file:

- [primesieve_error.hpp](#)

5.3 primesieve_iterator Struct Reference

C prime iterator, please refer to [iterator.h](#) for more information.

```
#include <iterator.h>
```

Public Attributes

- `size_t i`
Current index of the primes array.
- `size_t size`
Current number of primes in the primes array.
- `uint64_t start`
Generate primes $\geq$ start.
- `uint64_t stop_hint`
Generate primes $\leq$ stop_hint.
- `uint64_t * primes`
The primes array.
- `void * memory`
Pointer to internal IteratorData data structure.
- `int is_error`
Initialized to 0, set to 1 if any error occurs.

5.3.1 Detailed Description

C prime iterator, please refer to [iterator.h](#) for more information.

Examples

[prev_prime.c](#), and [primesieve_iterator.c](#).

5.3.2 Member Data Documentation

5.3.2.1 primes

```
uint64_t* primesieve_iterator::primes
```

The primes array.

The current smallest prime can be accessed using `primes[0]`. The current largest prime can be accessed using `primes[size-1]`.

The documentation for this struct was generated from the following file:

- [iterator.h](#)

Chapter 6

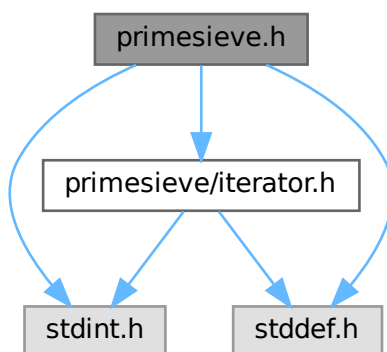
File Documentation

6.1 primesieve.h File Reference

primesieve C API.

```
#include <primesieve/iterator.h>
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for primesieve.h:



Macros

- `#define PRIMESIEVE_VERSION "12.12"`
- `#define PRIMESIEVE_VERSION_MAJOR 12`
- `#define PRIMESIEVE_VERSION_MINOR 12`
- `#define PRIMESIEVE_ERROR ((uint64_t) ~((uint64_t) 0))`

primesieve functions return `PRIMESIEVE_ERROR (UINT64_MAX)` if any error occurs.

Enumerations

- enum {
[SHORT_PRIMES](#) , [USHORT_PRIMES](#) , [INT_PRIMES](#) , [UINT_PRIMES](#) ,
[LONG_PRIMES](#) , [ULONG_PRIMES](#) , [LONGLONG_PRIMES](#) , [ULONGLONG_PRIMES](#) ,
[INT16_PRIMES](#) , [UINT16_PRIMES](#) , [INT32_PRIMES](#) , [UINT32_PRIMES](#) ,
[INT64_PRIMES](#) , [UINT64_PRIMES](#) }

Functions

- void * [primesieve_generate_primes](#) (uint64_t start, uint64_t stop, size_t *size, int type)
Get an array with the primes inside the interval [start, stop].
- void * [primesieve_generate_n_primes](#) (uint64_t n, uint64_t start, int type)
Get an array with the first n primes >= start.
- uint64_t [primesieve_nth_prime](#) (uint64_t n, uint64_t start)
Find the nth prime.
- uint64_t [primesieve_count_primes](#) (uint64_t start, uint64_t stop)
Count the primes within the interval [start, stop].
- uint64_t [primesieve_count_twins](#) (uint64_t start, uint64_t stop)
Count the twin primes within the interval [start, stop].
- uint64_t [primesieve_count_triplets](#) (uint64_t start, uint64_t stop)
Count the prime triplets within the interval [start, stop].
- uint64_t [primesieve_count_quadruplets](#) (uint64_t start, uint64_t stop)
Count the prime quadruplets within the interval [start, stop].
- uint64_t [primesieve_count_quintuplets](#) (uint64_t start, uint64_t stop)
Count the prime quintuplets within the interval [start, stop].
- uint64_t [primesieve_count_sextuplets](#) (uint64_t start, uint64_t stop)
Count the prime sextuplets within the interval [start, stop].
- void **primesieve_print_primes** (uint64_t start, uint64_t stop)
Print the primes within the interval [start, stop] to the standard output.
- void **primesieve_print_twins** (uint64_t start, uint64_t stop)
Print the twin primes within the interval [start, stop] to the standard output.
- void **primesieve_print_triplets** (uint64_t start, uint64_t stop)
Print the prime triplets within the interval [start, stop] to the standard output.
- void **primesieve_print_quadruplets** (uint64_t start, uint64_t stop)
Print the prime quadruplets within the interval [start, stop] to the standard output.
- void **primesieve_print_quintuplets** (uint64_t start, uint64_t stop)
Print the prime quintuplets within the interval [start, stop] to the standard output.
- void **primesieve_print_sextuplets** (uint64_t start, uint64_t stop)
Print the prime sextuplets within the interval [start, stop] to the standard output.
- uint64_t [primesieve_get_max_stop](#) (void)
Returns the largest valid stop number for primesieve.
- int **primesieve_get_sieve_size** (void)
Get the current set sieve size in KiB.
- int **primesieve_get_num_threads** (void)
Get the current set number of threads.
- void [primesieve_set_sieve_size](#) (int sieve_size)
Set the sieve size in KiB (kibibyte).
- void [primesieve_set_num_threads](#) (int num_threads)
Set the number of threads for use in [primesieve_count_\(\)](#) and [primesieve_nth_prime\(\)](#).*
- void **primesieve_free** (void *primes)
Deallocate a primes array created using the [primesieve_generate_primes\(\)](#) or [primesieve_generate_n_primes\(\)](#) functions.
- const char * **primesieve_version** (void)
Get the primesieve version number, in the form "i.j"

6.1.1 Detailed Description

primesieve C API.

primesieve is a library for quickly generating prime numbers. If an error occurs, primesieve functions with a `uint64_t` return type return `PRIMESIEVE_ERROR` and the corresponding error message is printed to the standard error stream. `libprimesieve` also sets the C `errno` variable to `EDOM` if an error occurs.

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6.1.2 Enumeration Type Documentation

6.1.2.1 anonymous enum

anonymous enum

Enumerator

<code>SHORT_PRIMES</code>	Generate primes of short type.
<code>USHORT_PRIMES</code>	Generate primes of unsigned short type.
<code>INT_PRIMES</code>	Generate primes of int type.
<code>UINT_PRIMES</code>	Generate primes of unsigned int type.
<code>LONG_PRIMES</code>	Generate primes of long type.
<code>ULONG_PRIMES</code>	Generate primes of unsigned long type.
<code>LONGLONG_PRIMES</code>	Generate primes of long long type.
<code>ULONGLONG_PRIMES</code>	Generate primes of unsigned long long type.
<code>INT16_PRIMES</code>	Generate primes of <code>int16_t</code> type.
<code>UINT16_PRIMES</code>	Generate primes of <code>uint16_t</code> type.
<code>INT32_PRIMES</code>	Generate primes of <code>int32_t</code> type.
<code>UINT32_PRIMES</code>	Generate primes of <code>uint32_t</code> type.
<code>INT64_PRIMES</code>	Generate primes of <code>int64_t</code> type.
<code>UINT64_PRIMES</code>	Generate primes of <code>uint64_t</code> type.

6.1.3 Function Documentation

6.1.3.1 `primesieve_count_primes()`

```
uint64_t primesieve_count_primes (
    uint64_t start,
    uint64_t stop )
```

Count the primes within the interval `[start, stop]`.

By default all CPU cores are used, use `primesieve_set_num_threads(int threads)` to change the number of threads.

Note that each call to `primesieve_count_primes()` incurs an initialization overhead of $O(\sqrt{\text{stop}})$ even if the interval `[start, stop]` is tiny. Hence if you have written an algorithm that makes many calls to `primesieve_count_primes()` it may be preferable to use a `primesieve::iterator` which needs to be initialized only once.

Examples

[count_primes.c](#).

6.1.3.2 `primesieve_count_quadruplets()`

```
uint64_t primesieve_count_quadruplets (
    uint64_t start,
    uint64_t stop )
```

Count the prime quadruplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve_set_num_threads\(int threads\)](#) to change the number of threads.

6.1.3.3 `primesieve_count_quintuplets()`

```
uint64_t primesieve_count_quintuplets (
    uint64_t start,
    uint64_t stop )
```

Count the prime quintuplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve_set_num_threads\(int threads\)](#) to change the number of threads.

6.1.3.4 `primesieve_count_sextuplets()`

```
uint64_t primesieve_count_sextuplets (
    uint64_t start,
    uint64_t stop )
```

Count the prime sextuplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve_set_num_threads\(int threads\)](#) to change the number of threads.

6.1.3.5 `primesieve_count_triplets()`

```
uint64_t primesieve_count_triplets (
    uint64_t start,
    uint64_t stop )
```

Count the prime triplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve_set_num_threads\(int threads\)](#) to change the number of threads.

6.1.3.6 primesieve_count_twins()

```
uint64_t primesieve_count_twins (
    uint64_t start,
    uint64_t stop )
```

Count the twin primes within the interval [start, stop].

By default all CPU cores are used, use [primesieve_set_num_threads\(int threads\)](#) to change the number of threads.

6.1.3.7 primesieve_generate_n_primes()

```
void * primesieve_generate_n_primes (
    uint64_t n,
    uint64_t start,
    int type )
```

Get an array with the first n primes $\geq$ start.

Parameters

<i>type</i>	The type of the primes to generate, e.g. INT_PRIMES.
-------------	--

In case an error occurs the error message is printed to the standard error stream and a NULL pointer is returned. libprimesieve also sets the C errno variable (from `<errno.h>`) to EDOM if any error occurs. The only advantage which checking errno (after [primesieve_generate_n_primes\(\)](#)) has over checking if a NULL pointer has been returned, is that errno is not set when calling `primesieve_generate_n_primes(0, start, type)` which is valid (but useless) and which returns a NULL pointer.

Examples

[primes_array.c](#).

6.1.3.8 primesieve_generate_primes()

```
void * primesieve_generate_primes (
    uint64_t start,
    uint64_t stop,
    size_t * size,
    int type )
```

Get an array with the primes inside the interval [start, stop].

Parameters

<i>size</i>	The size of the returned primes array.
<i>type</i>	The type of the primes to generate, e.g. INT_PRIMES.

In case an error occurs the error message is printed to the standard error stream, the size is set to 0 and a

NULL pointer is returned. In order to distinguish an "error" from "no primes found within [start, stop]" libprimesieve also sets the C errno variable (from <errno.h>) to EDOM if any error occurs. By checking errno after calling [primesieve_generate_primes\(\)](#) users can reliably detect errors.

Examples

[primes_array.c](#).

6.1.3.9 primesieve_get_max_stop()

```
uint64_t primesieve_get_max_stop (
    void )
```

Returns the largest valid stop number for primesieve.

Returns

$2^{64}-1$ (UINT64_MAX).

6.1.3.10 primesieve_nth_prime()

```
uint64_t primesieve_nth_prime (
    int64_t n,
    uint64_t start )
```

Find the nth prime.

By default all CPU cores are used, use [primesieve_set_num_threads\(int threads\)](#) to change the number of threads.

Note that each call to `primesieve_nth_prime(n, start)` incurs an initialization overhead of $O(\sqrt{\text{start}})$ even if `n` is tiny. Hence it is not a good idea to use [primesieve_nth_prime\(\)](#) repeatedly in a loop to get the next (or previous) prime. For this use case it is better to use a [primesieve::iterator](#) which needs to be initialized only once.

Parameters

<i>n</i>	if $n = 0$ finds the 1st prime $\geq$ start, if $n > 0$ finds the nth prime $>$ start, if $n < 0$ finds the nth prime $<$ start (backwards).
----------	--

Examples

[nth_prime.c](#).

6.1.3.11 primesieve_set_num_threads()

```
void primesieve_set_num_threads (
    int num_threads )
```

Set the number of threads for use in `primesieve_count_*`() and [primesieve_nth_prime\(\)](#).

By default all CPU cores are used.

6.1.3.12 primesieve_set_sieve_size()

```
void primesieve_set_sieve_size (
    int sieve_size )
```

Set the sieve size in KiB (kibibyte).

The best sieving performance is achieved with a sieve size of your CPU's L1 or L2 cache size (per core).

Precondition

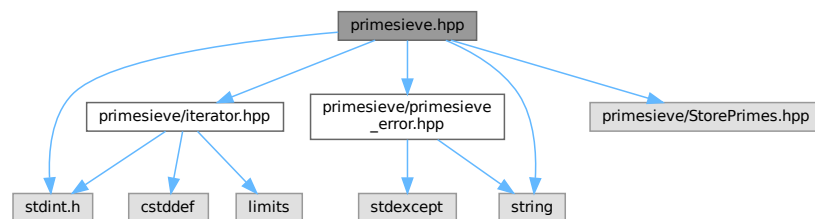
sieve_size >= 16 && <= 8192.

6.2 primesieve.hpp File Reference

primesieve C++ API.

```
#include <primesieve/iterator.hpp>
#include <primesieve/primesieve_error.hpp>
#include <primesieve/StorePrimes.hpp>
#include <stdint.h>
#include <string>
```

Include dependency graph for primesieve.hpp:



Macros

- `#define PRIMESIEVE_VERSION "12.12"`
- `#define PRIMESIEVE_VERSION_MAJOR 12`
- `#define PRIMESIEVE_VERSION_MINOR 12`

Functions

- `template<typename vect >`
`void primesieve::generate_primes (uint64_t stop, vect *primes)`
Appends the primes <= stop to the end of the primes vector.
- `template<typename vect >`
`void primesieve::generate_primes (uint64_t start, uint64_t stop, vect *primes)`
Appends the primes inside [start, stop] to the end of the primes vector.
- `template<typename vect >`
`void primesieve::generate_n_primes (uint64_t n, vect *primes)`

- Appends the first n primes to the end of the primes vector.*
 - `template<typename vect >`
`void primesieve::generate\_n\_primes (uint64_t n, uint64_t start, vect *primes)`
Appends the first n primes $\geq$ start to the end of the primes vector.
- `uint64_t primesieve::nth\_prime (int64_t n, uint64_t start=0)`
Find the n th prime.
- `uint64_t primesieve::count\_primes (uint64_t start, uint64_t stop)`
Count the primes within the interval [start, stop].
- `uint64_t primesieve::count\_twins (uint64_t start, uint64_t stop)`
Count the twin primes within the interval [start, stop].
- `uint64_t primesieve::count\_triplets (uint64_t start, uint64_t stop)`
Count the prime triplets within the interval [start, stop].
- `uint64_t primesieve::count\_quadruplets (uint64_t start, uint64_t stop)`
Count the prime quadruplets within the interval [start, stop].
- `uint64_t primesieve::count\_quintuplets (uint64_t start, uint64_t stop)`
Count the prime quintuplets within the interval [start, stop].
- `uint64_t primesieve::count\_sextuplets (uint64_t start, uint64_t stop)`
Count the prime sextuplets within the interval [start, stop].
- `void primesieve::print\_primes (uint64_t start, uint64_t stop)`
Print the primes within the interval [start, stop] to the standard output.
- `void primesieve::print\_twins (uint64_t start, uint64_t stop)`
Print the twin primes within the interval [start, stop] to the standard output.
- `void primesieve::print\_triplets (uint64_t start, uint64_t stop)`
Print the prime triplets within the interval [start, stop] to the standard output.
- `void primesieve::print\_quadruplets (uint64_t start, uint64_t stop)`
Print the prime quadruplets within the interval [start, stop] to the standard output.
- `void primesieve::print\_quintuplets (uint64_t start, uint64_t stop)`
Print the prime quintuplets within the interval [start, stop] to the standard output.
- `void primesieve::print\_sextuplets (uint64_t start, uint64_t stop)`
Print the prime sextuplets within the interval [start, stop] to the standard output.
- `uint64_t primesieve::get\_max\_stop ()`
Returns the largest valid stop number for primesieve.
- `int primesieve::get\_sieve\_size ()`
Get the current set sieve size in KiB.
- `int primesieve::get\_num\_threads ()`
Get the current set number of threads.
- `void primesieve::set\_sieve\_size (int sieve_size)`
Set the sieve size in KiB (kibibyte).
- `void primesieve::set\_num\_threads (int num_threads)`
Set the number of threads for use in [primesieve::count_](#)() and [primesieve::nth_prime](#)().*
- `std::string primesieve::primesieve\_version ()`
Get the primesieve version number, in the form "i.j".

6.2.1 Detailed Description

primesieve C++ API.

primesieve is a library for fast prime number generation, in case an error occurs a [primesieve::primesieve_error](#) exception (derived from `std::runtime_error`) is thrown.

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6.2.2 Function Documentation

6.2.2.1 count_primes()

```
uint64_t primesieve::count_primes (
    uint64_t start,
    uint64_t stop )
```

Count the primes within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set_num_threads\(int threads\)](#) to change the number of threads.

Note that each call to `count_primes()` incurs an initialization overhead of $O(\sqrt{\text{stop}})$ even if the interval [start, stop] is tiny. Hence if you have written an algorithm that makes many calls to `count_primes()` it may be preferable to use a [primesieve::iterator](#) which needs to be initialized only once.

Examples

[count_primes.cpp](#).

6.2.2.2 count_quadruplets()

```
uint64_t primesieve::count_quadruplets (
    uint64_t start,
    uint64_t stop )
```

Count the prime quadruplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set_num_threads\(int threads\)](#) to change the number of threads.

6.2.2.3 count_quintuplets()

```
uint64_t primesieve::count_quintuplets (
    uint64_t start,
    uint64_t stop )
```

Count the prime quintuplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set_num_threads\(int threads\)](#) to change the number of threads.

6.2.2.4 count_sextuplets()

```
uint64_t primesieve::count_sextuplets (
    uint64_t start,
    uint64_t stop )
```

Count the prime sextuplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set_num_threads\(int threads\)](#) to change the number of threads.

6.2.2.5 count_triplets()

```
uint64_t primesieve::count_triplets (
    uint64_t start,
    uint64_t stop )
```

Count the prime triplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set_num_threads\(int threads\)](#) to change the number of threads.

6.2.2.6 count_twins()

```
uint64_t primesieve::count_twins (
    uint64_t start,
    uint64_t stop )
```

Count the twin primes within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set_num_threads\(int threads\)](#) to change the number of threads.

6.2.2.7 generate_n_primes() [1/2]

```
template<typename vect >
void primesieve::generate_n_primes (
    uint64_t n,
    uint64_t start,
    vect * primes ) [inline]
```

Appends the first n primes $\geq$ start to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

6.2.2.8 generate_n_primes() [2/2]

```
template<typename vect >
void primesieve::generate_n_primes (
    uint64_t n,
    vect * primes ) [inline]
```

Appends the first n primes to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

Examples

[primes_vector.cpp](#).

6.2.2.9 generate_primes() [1/2]

```
template<typename vect >
void primesieve::generate_primes (
    uint64_t start,
    uint64_t stop,
    vect * primes ) [inline]
```

Appends the primes inside [start, stop] to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

6.2.2.10 generate_primes() [2/2]

```
template<typename vect >
void primesieve::generate_primes (
    uint64_t stop,
    vect * primes ) [inline]
```

Appends the primes $\leq$ stop to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

Examples

[primes_vector.cpp](#).

6.2.2.11 get_max_stop()

```
uint64_t primesieve::get_max_stop ( )
```

Returns the largest valid stop number for primesieve.

Returns

$2^{64}-1$ (UINT64_MAX).

6.2.2.12 nth_prime()

```
uint64_t primesieve::nth_prime (
    int64_t n,
    uint64_t start = 0 )
```

Find the nth prime.

By default all CPU cores are used, use [primesieve::set_num_threads\(int threads\)](#) to change the number of threads.

Note that each call to nth_prime(n, start) incurs an initialization overhead of $O(\sqrt{\text{start}})$ even if n is tiny. Hence it is not a good idea to use nth_prime() repeatedly in a loop to get the next (or previous) prime. For this use case it is better to use a [primesieve::iterator](#) which needs to be initialized only once.

Parameters

<i>n</i>	if $n = 0$ finds the 1st prime $\geq$ start, if $n > 0$ finds the n th prime $>$ start, if $n < 0$ finds the n th prime $<$ start (backwards).
----------	--

Examples

[nth_prime.cpp](#).

6.2.2.13 set_num_threads()

```
void primesieve::set_num_threads (
    int num_threads )
```

Set the number of threads for use in `primesieve::count_*`() and [primesieve::nth_prime\(\)](#).

By default all CPU cores are used.

6.2.2.14 set_sieve_size()

```
void primesieve::set_sieve_size (
    int sieve_size )
```

Set the sieve size in KiB (kibibyte).

The best sieving performance is achieved with a sieve size of your CPU's L1 or L2 cache size (per core).

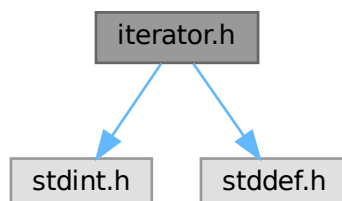
Precondition

`sieve_size` ≥ 16 && ≤ 8192 .

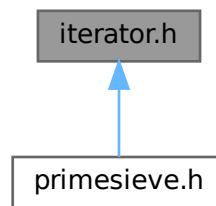
6.3 iterator.h File Reference

[primesieve_iterator](#) allows to easily iterate over primes both forwards and backwards.

```
#include <stdint.h>
#include <stddef.h>
Include dependency graph for iterator.h:
```



This graph shows which files directly or indirectly include this file:



Classes

- struct [primesieve_iterator](#)
C prime iterator, please refer to [iterator.h](#) for more information.

Macros

- #define **IF_UNLIKELY_PRIMESIEVE**(x) if (x)

Functions

- void **primesieve_init** ([primesieve_iterator](#) *it)
Initialize the primesieve iterator before first using it.
- void **primesieve_free_iterator** ([primesieve_iterator](#) *it)
Free all memory.
- void **primesieve_clear** ([primesieve_iterator](#) *it)
Reset the start number to 0 and free most memory.
- void **primesieve_jump_to** ([primesieve_iterator](#) *it, uint64_t start, uint64_t stop_hint)
Reset the primesieve iterator to start.
- void **primesieve_skipto** ([primesieve_iterator](#) *it, uint64_t start, uint64_t stop_hint)
Reset the primesieve iterator to start.
- void **primesieve_generate_next_primes** ([primesieve_iterator](#) *)
Used internally by [primesieve_next_prime\(\)](#).
- void **primesieve_generate_prev_primes** ([primesieve_iterator](#) *)
Used internally by [primesieve_prev_prime\(\)](#).
- static uint64_t **primesieve_next_prime** ([primesieve_iterator](#) *it)
Get the next prime.
- static uint64_t **primesieve_prev_prime** ([primesieve_iterator](#) *it)
Get the previous prime.

6.3.1 Detailed Description

[primesieve_iterator](#) allows to easily iterate over primes both forwards and backwards.

Generating the first prime has a complexity of $O(r \log \log r)$ operations with $r = n^{0.5}$, after that any additional prime is generated in amortized $O(\log n \log \log n)$ operations. The memory usage is about $\text{PrimePi}(n^{0.5}) * 8$ bytes.

The [primesieve_iterator.c](#) example shows how to use [primesieve_iterator](#). If any error occurs [primesieve_next_prime\(\)](#) and [primesieve_prev_prime\(\)](#) return `PRIMESIEVE_ERROR`. Furthermore [primesieve_iterator.is_error](#) is initialized to 0 and set to 1 if any error occurs.

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6.3.2 Function Documentation

6.3.2.1 [primesieve_clear\(\)](#)

```
void primesieve_clear (
    primesieve_iterator * it )
```

Reset the start number to 0 and free most memory.

Keeps some smaller data structures in memory (e.g. the `IteratorData` object) that are useful if the [primesieve_iterator](#) is reused. The remaining memory uses at most 2 kilobytes.

6.3.2.2 [primesieve_generate_next_primes\(\)](#)

```
void primesieve_generate_next_primes (
    primesieve_iterator * )
```

Used internally by [primesieve_next_prime\(\)](#).

[primesieve_generate_next_primes\(\)](#) fills (overwrites) the primes array with the next few primes ($\sim 2^{10}$) that are larger than the current largest prime in the primes array or with the primes $\geq$ start if the primes array is empty. Note that this function also updates the `i` & `size` member variables of the [primesieve_iterator](#) struct. The size of the primes array varies, but it is > 0 and usually close to 2^{10} . If an error occurs [primesieve_iterator.is_error](#) is set to 1 and the primes array will contain `PRIMESIEVE_ERROR`.

6.3.2.3 [primesieve_generate_prev_primes\(\)](#)

```
void primesieve_generate_prev_primes (
    primesieve_iterator * )
```

Used internally by [primesieve_prev_prime\(\)](#).

[primesieve_generate_prev_primes\(\)](#) fills (overwrites) the primes array with the next few primes $\sim O(\sqrt{n})$ that are smaller than the current smallest prime in the primes array or with the primes $\leq$ start if the primes array is empty. Note that this function also updates the `i` & `size` member variables of the [primesieve_iterator](#) struct. The size of the primes array varies, but it is > 0 and $\sim O(\sqrt{n})$. If an error occurs [primesieve_iterator.is_error](#) is set to 1 and the primes array will contain `PRIMESIEVE_ERROR`.

6.3.2.4 [primesieve_jump_to\(\)](#)

```
void primesieve_jump_to (
    primesieve_iterator * it,
    uint64_t start,
    uint64_t stop_hint )
```

Reset the primesieve iterator to start.

Parameters

<i>start</i>	Generate primes $\geq$ start (or $\leq$ start).
<i>stop_hint</i>	Stop number optimization hint. E.g. if you want to generate the primes $\leq$ 1000 use stop_hint = 1000, if you don't know use UINT64_MAX.

Examples

[prev_prime.c](#), and [primesieve_iterator.c](#).

6.3.2.5 primesieve_next_prime()

```
static uint64_t primesieve_next_prime (  
    primesieve_iterator * it ) [inline], [static]
```

Get the next prime.

Returns PRIMESIEVE_ERROR (UINT64_MAX) if any error occurs.

Examples

[primesieve_iterator.c](#).

6.3.2.6 primesieve_prev_prime()

```
static uint64_t primesieve_prev_prime (  
    primesieve_iterator * it ) [inline], [static]
```

Get the previous prime.

primesieve_prev_prime(n) returns 0 for $n \leq 2$. Note that [primesieve_next_prime\(\)](#) runs up to 2x faster than [primesieve_prev_prime\(\)](#). Hence if the same algorithm can be written using either [primesieve_prev_prime\(\)](#) or [primesieve_next_prime\(\)](#) it is preferable to use [primesieve_next_prime\(\)](#).

Examples

[prev_prime.c](#).

6.3.2.7 primesieve_skipto()

```
void primesieve_skipto (  
    primesieve_iterator * it,  
    uint64_t start,  
    uint64_t stop_hint )
```

Reset the primesieve iterator to start.

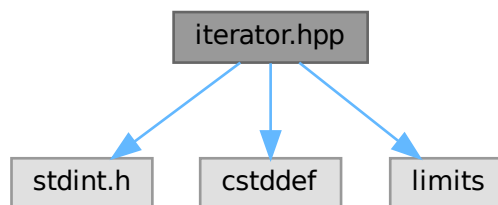
Parameters

<i>start</i>	Generate primes > start (or < start).
<i>stop_hint</i>	Stop number optimization hint. E.g. if you want to generate the primes <= 1000 use stop_hint = 1000, if you don't know use UINT64_MAX.

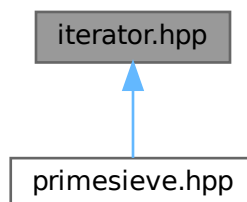
6.4 iterator.hpp File Reference

[primesieve::iterator](#) allows to easily iterate (forwards and backwards) over prime numbers.

```
#include <stdint.h>
#include <cstdint>
#include <limits>
Include dependency graph for iterator.hpp:
```



This graph shows which files directly or indirectly include this file:



Classes

- struct [primesieve::iterator](#)
[primesieve::iterator](#) allows to easily iterate over primes both forwards and backwards.

Macros

- `#define IF_UNLIKELY_PRIMESIEVE(x) if (x)`

6.4.1 Detailed Description

`primesieve::iterator` allows to easily iterate (forwards and backwards) over prime numbers.

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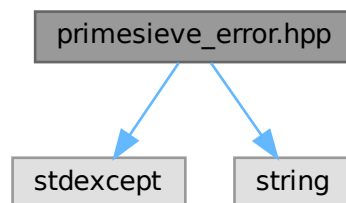
6.5 primesieve_error.hpp File Reference

The `primesieve_error` class is used for all exceptions within `primesieve`.

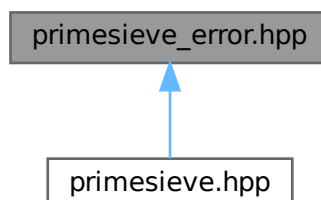
```
#include <stdexcept>
```

```
#include <string>
```

Include dependency graph for `primesieve_error.hpp`:



This graph shows which files directly or indirectly include this file:



Classes

- class `primesieve::primesieve_error`

primesieve throws a `primesieve_error` exception if an error occurs e.g.

6.5.1 Detailed Description

The `primesieve_error` class is used for all exceptions within `primesieve`.

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Chapter 7

Examples

7.1 count_primes.cpp

This example shows how to count primes.

This example shows how to count primes.

```
#include <primesieve.hpp>
#include <stdint.h>
#include <iostream>

int main()
{
    uint64_t count = primesieve::count_primes(0, 1000);
    std::cout << "Primes <= 1000: " << count << std::endl;

    return 0;
}
```

7.2 primesieve_iterator.cpp

Iterate over primes using `primesieve::iterator`.

Iterate over primes using `primesieve::iterator`.

```
#include <primesieve.hpp>
#include <cstdlib>
#include <iostream>

int main(int argc, char** argv)
{
    uint64_t limit = 10000000000ull;

    if (argc > 1)
        limit = std::atol(argv[1]);

    primesieve::iterator it(0, limit);
    uint64_t prime = it.next_prime();
    uint64_t sum = 0;

    // Iterate over the primes <= 10^9
    for (; prime <= limit; prime = it.next_prime())
        sum += prime;

    std::cout << "Sum of primes <= " << limit << ": " << sum << std::endl;

    // Note that since sum is a 64-bit variable the result
    // will be incorrect (due to integer overflow) if
    // limit > 10^10. However we do allow limits > 10^10
    // since this is useful for benchmarking.
    if (limit > 10000000000ull)
        std::cerr << "Warning: sum is likely incorrect due to 64-bit integer overflow!" << std::endl;

    return 0;
}
```

7.3 nth_prime.cpp

Find the nth prime.

Find the nth prime.

```
#include <primesieve.hpp>
#include <stdint.h>
#include <iostream>
#include <cstdlib>

int main(int, char** argv)
{
    uint64_t n = 1000;

    if (argv[1])
        n = std::atol(argv[1]);

    uint64_t nth_prime = primesieve::nth_prime(n);
    std::cout << n << "th prime = " << nth_prime << std::endl;

    return 0;
}
```

7.4 prev_prime.cpp

Iterate backwards over primes using `primesieve::iterator`.

Iterate backwards over primes using `primesieve::iterator`.

```
#include <primesieve.hpp>
#include <cstdlib>
#include <iostream>

int main(int argc, char** argv)
{
    uint64_t limit = 10000000000ull;

    if (argc > 1)
        limit = std::atol(argv[1]);

    primesieve::iterator it;
    it.jump_to(limit);
    uint64_t prime = it.prev_prime();
    uint64_t sum = 0;

    // Backwards iterate over the primes <= 10^9
    for (; prime > 0; prime = it.prev_prime())
        sum += prime;

    std::cout << "Sum of primes <= " << limit << ": " << sum << std::endl;

    // Note that since sum is a 64-bit variable the result
    // will be incorrect (due to integer overflow) if
    // limit > 10^10. However we do allow limits > 10^10
    // since this is useful for benchmarking.
    if (limit > 10000000000ull)
        std::cerr << "Warning: sum is likely incorrect due to 64-bit integer overflow!" << std::endl;

    return 0;
}
```

7.5 primes_vector.cpp

Fill a `std::vector` with primes.

Fill a `std::vector` with primes.

```
#include <primesieve.hpp>
```

```

#include <vector>

int main()
{
    std::vector<int> primes;

    // Fill the primes vector with the primes <= 1000
    primesieve::generate_primes(1000, &primes);

    primes.clear();

    // Fill the primes vector with the primes inside [1000, 2000]
    primesieve::generate_primes(1000, 2000, &primes);

    primes.clear();

    // Fill the primes vector with the first 1000 primes
    primesieve::generate_n_primes(1000, &primes);

    primes.clear();

    // Fill the primes vector with the first 10 primes >= 1000
    primesieve::generate_n_primes(10, 1000, &primes);

    return 0;
}

```

7.6 count_primes.c

C program that shows how to count primes.

C program that shows how to count primes.

```

#include <primesieve.h>
#include <inttypes.h>
#include <stdio.h>

int main(void)
{
    uint64_t count = primesieve_count_primes(0, 1000);
    printf("Primes <= 1000: %" PRIu64 "\n", count);

    return 0;
}

```

7.7 prev_prime.c

Iterate backwards over primes using [primesieve_iterator](#).

Iterate backwards over primes using [primesieve_iterator](#). Note that [primesieve_next_prime\(\)](#) runs up to 2x faster and uses only half as much memory as [primesieve_prev_prime\(\)](#). Hence if it is possible to write the same algorithm using either [primesieve_prev_prime\(\)](#) or [primesieve_next_prime\(\)](#) then it is preferable to use [primesieve_next_prime\(\)](#).

```

#include <primesieve.h>
#include <inttypes.h>
#include <stdlib.h>
#include <stdio.h>

int main(int argc, char** argv)
{
    uint64_t limit = 1000000000000ull;

    if (argc > 1)
        limit = atol(argv[1]);

    primesieve_iterator it;
    primesieve_init(&it);

    /* primesieve_jump_to(&it, start_number, stop_hint) */
    primesieve_jump_to(&it, limit, 0);
    uint64_t prime;

```

```

uint64_t sum = 0;

/* Backwards iterate over the primes <= limit */
while ((prime = primesieve_prev_prime(&it)) > 0)
    sum += prime;

primesieve_free_iterator(&it);
printf("Sum of the primes: %" PRIu64 "\n", sum);

/* Note that since sum is a 64-bit variable the result
 * will be incorrect (due to integer overflow) if
 * limit > 10^10. However we do allow limits > 10^10
 * since this is useful for benchmarking. */
if (limit > 10000000000ull)
    printf("Warning: sum is likely incorrect due to 64-bit integer overflow!");

return 0;
}

```

7.8 primesieve_iterator.c

Iterate over primes using C `primesieve_iterator`.

Iterate over primes using C `primesieve_iterator`.

```

#include <primesieve.h>
#include <inttypes.h>
#include <stdio.h>
#include <stdlib.h>

int main(int argc, char** argv)
{
    uint64_t limit = 10000000000ull;

    if (argc > 1)
        limit = atol(argv[1]);

    primesieve_iterator it;
    primesieve_init(&it);

    /* Indicate exact bounds to improve performance */
    primesieve_jump_to(&it, 0, limit);

    uint64_t sum = 0;
    uint64_t prime = 0;

    /* Iterate over the primes <= 10^9 */
    while ((prime = primesieve_next_prime(&it)) <= limit)
        sum += prime;

    printf("Sum of the primes <= %" PRIu64 ": %" PRIu64 "\n", limit, sum);

    primesieve_free_iterator(&it);

    return 0;
}

```

7.9 nth_prime.c

C program that finds the nth prime.

C program that finds the nth prime.

```

#include <primesieve.h>
#include <stdlib.h>
#include <inttypes.h>
#include <stdio.h>

int main(int argc, char** argv)
{
    uint64_t n = 1000;

    if (argc > 1 && argv[1])

```

```
    n = atol(argv[1]);

    uint64_t prime = primesieve_nth_prime(n, 0);
    printf("%" PRIu64 "th prime = %" PRIu64 "\n", n, prime);

    return 0;
}
```

7.10 primes_array.c

Generate an array of primes.

Generate an array of primes.

```
#include <primesieve.h>
#include <stdio.h>

int main(void)
{
    uint64_t start = 0;
    uint64_t stop = 1000;
    size_t i;
    size_t size;

    /* Get an array with the primes <= 1000 */
    int* primes = (int*) primesieve_generate_primes(start, stop, &size, INT_PRIMES);

    for (i = 0; i < size; i++)
        printf("%i\n", primes[i]);

    primesieve_free(primes);
    uint64_t n = 1000;

    /* Get an array with the first 1000 primes */
    primes = (int*) primesieve_generate_n_primes(n, start, INT_PRIMES);

    for (i = 0; i < n; i++)
        printf("%i\n", primes[i]);

    primesieve_free(primes);
    return 0;
}
```


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