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# Concept reference

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## Concepts

- [Assignable](#)
- [InputIterator](#)
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- [DefaultConstructible](#)
- [CopyConstructible](#)
- [EqualityComparable](#)
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- [SignedInteger](#)

# Concept Assignable

Assignable

## Description

Assignable types must have copy constructors, `operator=` for assignment, and the `swap()` function defined.

## Refinement of

- [CopyConstructible](#)

## Notation

$X$      A type playing the role of assignable-type in the [Assignable](#) concept.

$x, y$     Objects of type  $X$

## Valid expressions

| Name       | Expression              | Type  | Semantics                            |
|------------|-------------------------|-------|--------------------------------------|
| Assignment | <code>x = y</code>      | $X$ & | Require <code>operator=</code>       |
| Swap       | <code>swap(x, y)</code> | void  | Require <code>swap()</code> function |

## Models

- `int`

## See also

- [CopyConstructible](#)

# Concept InputIterator

InputIterator

## Description

An input iterator is an iterator that can read through a sequence of values. It is single-pass (old values of the iterator cannot be re-used), and read-only.

An input iterator represents a position in a sequence. Therefore, the iterator can point into the sequence (returning a value when dereferenced and being incrementable), or be off-the-end (and not dereferenceable or incrementable).

## Refinement of

- [Assignable](#)
- [DefaultConstructible](#)
- [EqualityComparable](#)

## Associated types

- **value\_type**

```
std::iterator_traits<Iter>::value_type
```

The value type of the iterator (not necessarily what `*i` returns)

- **difference\_type**

```
std::iterator_traits<Iter>::difference_type
```

The difference type of the iterator

- **category**

```
std::iterator_traits<Iter>::iterator_category
```

The category of the iterator

## Notation

**Iter**     A type playing the role of iterator-type in the [InputIterator](#) concept.

**i, j**     Objects of type **Iter**

**x**        Object of type **value\_type**

## Type expressions

Category tag                      category must be derived from `std::input_iterator_tag`, a model of [DefaultConstructible](#), and a model of [CopyConstructible](#).

Value type copy constructibility    **value\_type** must be a model of [CopyConstructible](#).

Difference type properties        **difference\_type** must be a model of [SignedInteger](#).

## Valid expressions

| Name                          | Expression        | Type                                   | Precondition                                      | Semantics  | Postcondition                                    |
|-------------------------------|-------------------|--|---|--|--|
| Dereference                   | <code>*i</code>   | Convertible to <code>value_type</code> | <code>i</code> is incrementable (not off-the-end) |  |  |
| Preincrement                  | <code>++i</code>  | Iter &                                 | <code>i</code> is incrementable (not off-the-end) |  |  |
| Postincrement                 | <code>i++</code>  |  | <code>i</code> is incrementable (not off-the-end) | Equivalent to <code>(void)(++i)</code>                         | <code>i</code> is dereferenceable or off-the-end |
| Postincrement and dereference | <code>*i++</code> | Convertible to <code>value_type</code> | <code>i</code> is incrementable (not off-the-end) | Equivalent to <code>{value_type t = *i; ++i; return t;}</code> | <code>i</code> is dereferenceable or off-the-end |

## Complexity

All iterator operations must take amortized constant time.

## Models

- `std::istream_iterator`

## See also

- [DefaultConstructible](#)
- [EqualityComparable](#)
- [ForwardIterator](#)
- [OutputIterator](#)

# Concept OutputIterator

OutputIterator

## Description

An output iterator is an iterator that can write a sequence of values. It is single-pass (old values of the iterator cannot be re-used), and write-only.

An output iterator represents a position in a (possibly infinite) sequence. Therefore, the iterator can point into the sequence (returning a value when dereferenced and being incrementable), or be off-the-end (and not dereferenceable or incrementable).

## Associated types

- **value\_type**

```
std::iterator_traits<Iter>::value_type
```

The stated value type of the iterator (should be `void` for an output iterator that does not model some other iterator concept).

- **difference\_type**

```
std::iterator_traits<Iter>::difference_type
```

The difference type of the iterator

- **category**

```
std::iterator_traits<Iter>::iterator_category
```

The category of the iterator

## Notation

|           |   |
|-----------|---|
| Iter      | A type playing the role of iterator-type in the <a href="#">OutputIterator</a> concept. |
| ValueType | A type playing the role of value-type in the <a href="#">OutputIterator</a> concept.    |
| i, j      | Objects of type Iter  |
| x         | Object of type ValueType  |

## Type expressions

The type Iter must be a model of [Assignable](#).

The type ValueType must be a model of [Assignable](#).

The type Iter must be a model of [DefaultConstructible](#).

The type Iter must be a model of [EqualityComparable](#).

Category tag      category must be derived from `std::output_iterator_tag`, a model of [DefaultConstructible](#), and a model of [CopyConstructible](#).

Difference type properties      difference\_type must be a model of [SignedInteger](#).

## Valid expressions

| Name                                   | Expression            | Type   | Precondition                                      | Semantics                                   | Postcondition  |
|--|-----------------------|--------|---|---|--|
| Dereference                            | <code>*i</code>       |        | <code>i</code> is incrementable (not off-the-end) |   |  |
| Dereference and assign                 | <code>*i = x</code>   |        | <code>i</code> is incrementable (not off-the-end) |   | <code>*i</code> may not be written to again until it has been incremented. |
| Preincrement                           | <code>++i</code>      | Iter & | <code>i</code> is incrementable (not off-the-end) |   |  |
| Postincrement                          | <code>i++</code>      |        | <code>i</code> is incrementable (not off-the-end) | Equivalent to <code>(void) (++i)</code>     | <code>i</code> is dereferenceable or off-the-end                           |
| Postincrement, dereference, and assign | <code>*i++ = x</code> |        | <code>i</code> is incrementable (not off-the-end) | Equivalent to <code>{ *i = t; ++i; }</code> | <code>i</code> is dereferenceable or off-the-end                           |

## Complexity

All iterator operations must take amortized constant time.

## Models

- `std::ostream_iterator`, ...
- `std::insert_iterator`, ...
- `std::front_insert_iterator`, ...
- `std::back_insert_iterator`, ...

# Concept ForwardIterator

ForwardIterator

## Description

A forward iterator is an iterator that can read through a sequence of values. It is multi-pass (old values of the iterator can be re-used), and can be either mutable (data pointed to by it can be changed) or not mutable.

An iterator represents a position in a sequence. Therefore, the iterator can point into the sequence (returning a value when dereferenced and being incrementable), or be off-the-end (and not dereferenceable or incrementable).

## Refinement of

- [InputIterator](#)
- [OutputIterator](#)

## Associated types

- **value\_type**

```
std::iterator_traits<Iter>::value_type
```

The value type of the iterator

- **category**

```
std::iterator_traits<Iter>::iterator_category
```

The category of the iterator

## Notation

**Iter**      A type playing the role of iterator-type in the [ForwardIterator](#) concept.

**i, j**      Objects of type Iter

**x**          Object of type value\_type

## Type expressions

Category tag      category must be derived from std::forward\_iterator\_tag.

## Valid expressions

| Name          | Expression  | Type                                 | Precondition                         | Semantics   | Postcondition                          |
|---------------|---|--------------------------------------|--------------------------------------|---|--|
| Dereference   | *i  | const-if-not-mutable<br>value_type & | i is incrementable (not off-the-end) |   |  |
| Member access | i->{member-name}<br>(return type is<br>pointer-to-object<br>type) | const-if-not-mutable<br>value_type * | i is incrementable (not off-the-end) |   |  |
| Preincrement  | ++i   | Iter &                               | i is incrementable (not off-the-end) |   |  |
| Postincrement | i++   | Iter                                 | i is incrementable (not off-the-end) | Equivalent to<br>{Iter j = i;<br>++i; return<br>j;} | i is dereferenceable or<br>off-the-end |

## Complexity

All iterator operations must take amortized constant time.

## Invariants

Predecrement must return object      `&i = &(++i)`

Unique path through sequence      `i == j` implies `++i == ++j`

## Models

- `T *`
- `std::hash_set<T>::iterator`

## See also

- [BidirectionalIterator](#)



# Concept BidirectionalIterator

BidirectionalIterator

## Description

A bidirectional iterator is an iterator that can read through a sequence of values. It can move in either direction through the sequence, and can be either mutable (data pointed to by it can be changed) or not mutable.

An iterator represents a position in a sequence. Therefore, the iterator can point into the sequence (returning a value when dereferenced and being incrementable), or be off-the-end (and not dereferenceable or incrementable).

## Refinement of

- [ForwardIterator](#)

## Associated types

- **value\_type**

```
std::iterator_traits<Iter>::value_type
```

The value type of the iterator

- **category**

```
std::iterator_traits<Iter>::iterator_category
```

The category of the iterator

## Notation

**Iter**     A type playing the role of iterator-type in the [BidirectionalIterator](#) concept.

**i, j**     Objects of type **Iter**

**x**     Object of type **value\_type**

## Type expressions

Category tag     category must be derived from `std::bidirectional_iterator_tag`.

## Valid expressions

| Name          | Expression | Type   | Precondition   | Semantics                                  | Postcondition                       |
|---------------|------------|--------|--|--|-------------------------------------|
| Predecrement  | --i        | Iter & | i is incrementable (not off-the-end) and some dereferenceable iterator j exists such that i == ++j |  |                                     |
| Postdecrement | i--        | Iter   | Same as for predecrement   | Equivalent to {Iter j = i; --i; return j;} | i is dereferenceable or off-the-end |

## Complexity

All iterator operations must take amortized constant time.

## Invariants

Predecrement must return object      `&i = &(--i)`

Unique path through sequence      `i == j` implies `--i == --j`

Increment and decrement are in-      `++i`; `--i`; and `--i`; `++i`; must end up with the value of `i` unmodified, if `i` both of the  
verses      operations in the pair are valid.

## Models

- `T*`
- `std::list<T>::iterator`

## See also

- [RandomAccessIterator](#)

# Concept `RandomAccessIterator`

`RandomAccessIterator`

## Description

A random access iterator is an iterator that can read through a sequence of values. It can move in either direction through the sequence (by any amount in constant time), and can be either mutable (data pointed to by it can be changed) or not mutable.

An iterator represents a position in a sequence. Therefore, the iterator can point into the sequence (returning a value when dereferenced and being incrementable), or be off-the-end (and not dereferenceable or incrementable).

## Refinement of

- [BidirectionalIterator](#)
- [LessThanComparable](#)

## Associated types

- **value\_type**

```
std::iterator_traits<Iter>::value_type
```

The value type of the iterator

- **category**

```
std::iterator_traits<Iter>::iterator_category
```

The category of the iterator

- **difference\_type**

```
std::iterator_traits<Iter>::difference_type
```

The difference type of the iterator (measure of the number of steps between two iterators)

## Notation

|                      |   |
|----------------------|---|
| <code>Iter</code>    | A type playing the role of iterator-type in the <a href="#">RandomAccessIterator</a> concept. |
| <code>i, j</code>    | Objects of type <code>Iter</code>   |
| <code>x</code>       | Object of type <code>value_type</code>  |
| <code>n</code>       | Object of type <code>difference_type</code>   |
| <code>int_off</code> | Object of type <code>int</code>   |

## Type expressions

Category tag      category must be derived from `std::random_access_iterator_tag`.

## Valid expressions

| Name                                     | Expression                | Type                              | Semantics   |
|--|---------------------------|-----------------------------------|---|
| Motion                                   | <code>i += n</code>       | Iter &                            | Equivalent to applying <code>i++</code> <code>n</code> times if <code>n</code> is positive, applying <code>i--</code> <code>-n</code> times if <code>n</code> is negative, and to a null operation if <code>n</code> is zero. |
| Motion (with integer offset)             | <code>i += int_off</code> | Iter &                            | Equivalent to applying <code>i++</code> <code>n</code> times if <code>n</code> is positive, applying <code>i--</code> <code>-n</code> times if <code>n</code> is negative, and to a null operation if <code>n</code> is zero. |
| Subtractive motion                       | <code>i -= n</code>       | Iter &                            | Equivalent to <code>i += (-n)</code>  |
| Subtractive motion (with integer offset) | <code>i -= int_off</code> | Iter &                            | Equivalent to <code>i += (-n)</code>  |
| Addition                                 | <code>i + n</code>        | Iter                              | Equivalent to <code>{Iter j = i; j += n; return j;}</code>  |
| Addition with integer                    | <code>i + int_off</code>  | Iter                              | Equivalent to <code>{Iter j = i; j += n; return j;}</code>  |
| Addition (count first)                   | <code>n + i</code>        | Iter                              | Equivalent to <code>i + n</code>  |
| Addition with integer (count first)      | <code>int_off + i</code>  | Iter                              | Equivalent to <code>i + n</code>  |
| Subtraction                              | <code>i - n</code>        | Iter                              | Equivalent to <code>i + (-n)</code>   |
| Subtraction with integer                 | <code>i - int_off</code>  | Iter                              | Equivalent to <code>i + (-n)</code>   |
| Distance                                 | <code>i - j</code>        | difference_type                   | The number of times <code>i</code> must be incremented (or decremented if the result is negative) to reach <code>j</code> . Not defined if <code>j</code> is not reachable from <code>i</code> .                              |
| Element access                           | <code>i[n]</code>         | const-if-not-mutable value_type & | Equivalent to <code>*(i + n)</code>   |
| Element access with integer index        | <code>i[int_off]</code>   | const-if-not-mutable value_type & | Equivalent to <code>*(i + n)</code>   |

## Complexity

All iterator operations must take amortized constant time.

## Models

- `T *`
- `std::vector<T>::iterator`
- `std::vector<T>::const_iterator`
- `std::deque<T>::iterator`
- `std::deque<T>::const_iterator`

## See also

- [LessThanComparable](#)

# Concept DefaultConstructible

DefaultConstructible

## Description

DefaultConstructible objects only need to have a default constructor.

## Notation

X A type playing the role of default-constructible-type in the [DefaultConstructible](#) concept.

## Valid expressions

| Name         | Expression | Type | Semantics  |
|--------------|------------|------|--|
| Construction | X()        | X    | Construct an instance of the type with default parameters. |

## Models

- `int`
- `std::vector<double>`

# Concept CopyConstructible

CopyConstructible

## Description

Copy constructible types must be able to be constructed from another member of the type.

## Notation

$X$  A type playing the role of copy-constructible-type in the [CopyConstructible](#) concept.

$x, y$  Objects of type  $X$

## Valid expressions

| Name              | Expression | Type | Semantics                 |
|-------------------|------------|------|---------------------------|
| Copy construction | $X(x)$     | $X$  | Require copy constructor. |

## Models

- `int`

# Concept EqualityComparable

EqualityComparable

## Description

Equality Comparable types must have == and != operators.

## Notation

$X$      A type playing the role of comparable-type in the [EqualityComparable](#) concept.

$x, y$    Objects of type  $X$

## Valid expressions

| Name            | Expression | Type                |
|-----------------|------------|---------------------|
| Equality test   | $x == y$   | Convertible to bool |
| Inequality test | $x != y$   | Convertible to bool |

## Models

- `int`
- `std::vector<int>`



# Concept LessThanComparable

LessThanComparable

## Description

LessThanComparable types must have `<`, `>`, `<=`, and `>=` operators.

## Notation

$X$  A type playing the role of comparable-type in the [LessThanComparable](#) concept.

$x, y$  Objects of type  $X$

## Valid expressions

| Name                     | Expression | Type                | Semantics   |
|--------------------------|------------|---------------------|---|
| Less than                | $x < y$    | Convertible to bool | Determine if one value is less than another.                |
| Less than or equal       | $x \leq y$ | Convertible to bool | Determine if one value is less than or equal to another.    |
| Greater than             | $x > y$    | Convertible to bool | Determine if one value is greater than another.             |
| Greater than or equal to | $x \geq y$ | Convertible to bool | Determine if one value is greater than or equal to another. |

## Models

- `int`

# Concept `SignedInteger`

`SignedInteger`

## Refinement of

- [CopyConstructible](#)
- [Assignable](#)
- [DefaultConstructible](#)
- [EqualityComparable](#)
- [LessThanComparable](#)

## Notation

`T`      A type playing the role of integral-type in the [SignedInteger](#) concept.

`x`, `y`,  
`z`      Objects of type `T`

`a`, `b`      Objects of type `int`

## Type expressions

Conversion to `int`      `T` must be convertible to `int`.

## Valid expressions

| Name                                   | Expression   | Type                |
|--|--|---------------------|
| Conversion from int                    | $T(a)$   | T                   |
| Preincrement                           | $++x$  | T &                 |
| Predecrement                           | $--x$  | T &                 |
| Postincrement                          | $x++$  | T                   |
| Postdecrement                          | $x--$  | T                   |
| Sum                                    | $x + y$  | T                   |
| Sum with int                           | $x + a$  | T                   |
| Sum-assignment                         | $x += y$   | T &                 |
| Sum-assignment with int                | $x += a$   | T &                 |
| Difference                             | $x - y$  | T                   |
| Difference with int                    | $x - a$  | T                   |
| Product                                | $x * y$  | T                   |
| Product with int                       | $x * a$  | T                   |
| Product-assignment with int            | $x *= a$   | T &                 |
| Product with int on left               | $a * x$  | T                   |
| Quotient                               | $x / y$  | T                   |
| Quotient with int                      | $x / a$  | T                   |
| Right-shift                            | $x \gg y$  | T                   |
| Right-shift with int                   | $x \gg a$  | T                   |
| Right-shift-assignment with int        | $x \gg= a$   | T &                 |
| Less-than comparison                   | $x < y$  | Convertible to bool |
| Less-than comparison with int          | $x < a$  | Convertible to bool |
| Less-than comparison with size_t       | $x < \text{boost::sample\_value} < \text{std::size\_t}>()$ | Convertible to bool |
| Greater-than comparison                | $x > y$  | Convertible to bool |
| Greater-than comparison with int       | $x > a$  | Convertible to bool |
| Less-than-or-equal comparison          | $x \leq y$   | Convertible to bool |
| Less-than-or-equal comparison with int | $x \leq a$   | Convertible to bool |
| Greater-than-or-equal comparison       | $x \geq y$   | Convertible to bool |

| Name  | Expression | Type                |
|---|------------|---------------------|
| Greater-than-or-equal comparison with int         | $x \geq a$ | Convertible to bool |
| Greater-than-or-equal comparison with int on left | $a \geq x$ | Convertible to bool |
| Equality comparison                               | $x == y$   | Convertible to bool |
| Equality comparison with int                      | $x == a$   | Convertible to bool |