Spirit 2.1

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Table of Contents

This is the documentation of the newest version of Spirit (currently, V2.1). If you're looking for the documentation of Spirit's previous version (formerly Spirit V1.8), see *Spirit.Classic*.

Preface

> *"Examples of designs that meet most of the criteria for "goodness" (easy to understand, flexible, efficient) are a recursive-descent parser, which is traditional procedural code. Another example is the STL, which is a generic library of containers and algorithms depending crucially on both traditional procedural code and on parametric polymorphism."* **--Bjarne Stroustrup**

History

80s

In the mid-80s, Joel wrote his first calculator in Pascal. Such an unforgettable coding experience, he was amazed at how a mutually recursive set of functions can model a grammar specification. In time, the skills he acquired from that academic experience became very practical as he was tasked to do some parsing. For instance, whenever he needed to perform any form of binary or text I/O, he tried to approach each task somewhat formally by writing a grammar using Pascal-like syntax diagrams and then a corresponding recursive-descent parser. This process worked very well.

90s

The arrival of the Internet and the World Wide Web magnified the need for parsing a thousand-fold. At one point Joel had to write an HTML parser for a Web browser project. Using the W3C formal specifications, he easily wrote a recursive-descent HTML parser. With the influence of the Internet, RFC specifications were abundent. SGML, HTML, XML, email addresses and even those seemingly trivial URLs were all formally specified using small EBNF-style grammar specifications. Joel had more parsing to do, and he wished for a tool similar to larger parser generators such as YACC and ANTLR, where a parser is built automatically from a grammar specification.

This ideal tool would be able to parse anything from email addresses and command lines, to XML and scripting languages. Scalability was a primary goal. The tool would be able to do this without incurring a heavy development load, which was not possible with the above mentioned parser generators. The result was Spirit.

Spirit was a personal project that was conceived when Joel was involved in R&D in Japan. Inspired by the GoF's composite and interpreter patterns, he realized that he can model a recursive-descent parser with hierarchical-object composition of primitives (terminals) and composites (productions). The original version was implemented with run-time polymorphic classes. A parser was generated at run time by feeding in production rule strings such as:

```
"prod ::= {'A' | 'B'} 'C';"
```

A compile function compiled the parser, dynamically creating a hierarchy of objects and linking semantic actions on the fly. A very early text can be found here: pre-Spirit.

2001 to 2006

Version 1.0 to 1.8 was a complete rewrite of the original Spirit parser using expression templates and static polymorphism, inspired by the works of Todd Veldhuizen (Expression Templates, C++ Report, June 1995). Initially, the static-Spirit version was meant only to replace the core of the original dynamic-Spirit. Dynamic-Spirit needed a parser to implement itself anyway. The original employed a hand-coded recursive-descent parser to parse the input grammar specification strings. It was at this time when Hartmut Kaiser joined the Spirit development.

After its initial "open-source" debut in May 2001, static-Spirit became a success. At around November 2001, the Spirit website had an activity percentile of 98%, making it the number one parser tool at Source Forge at the time. Not bad for a niche project like a parser library. The "static" portion of Spirit was forgotten and static-Spirit simply became Spirit. The library soon evolved to acquire more dynamic features.

Spirit was formally accepted into Boost in October 2002. Boost is a peer-reviewed, open collaborative development effort around a collection of free Open Source C++ libraries covering a wide range of domains. The Boost Libraries have become widely known as an industry standard for design and implementation quality, robustness, and reusability.

2007

Over the years, especially after Spirit was accepted into Boost, Spirit has served its purpose quite admirably. **Classic-Spirit** (versions prior to 2.0) focused on transduction parsing, where the input string is merely translated to an output string. Many parsers fall into the transduction type. When the time came to add attributes to the parser library, it was done in a rather ad-hoc manner, with the goal being 100% backward compatible with Classic Spirit. As a result, some parsers have attributes, some don't.

Spirit V2 is another major rewrite. Spirit V2 grammars are fully attributed (see Attribute Grammar) which means that all parser components have attributes. To do this efficiently and elegantly, we had to use a couple of infrastructure libraries. Some did not exist, some were quite new when Spirit debuted, and some needed work. Boost.Mpl is an important infrastructure library, yet is not sufficient to implement Spirit V2. Another library had to be written: Boost.Fusion. Fusion sits between MPL and STL --between compile time and runtime -- mapping types to values. Fusion is a direct descendant of both MPL and Boost.Tuples. Fusion is now a full-fledged Boost library. Phoenix also had to be beefed up to support Spirit V2. The result is Boost.Phoenix. Last but not least, Spirit V2 uses an Expression Templates library called Boost.Proto.

Even though it has evolved and matured to become a multi-module library, Spirit is still used for micro-parsing tasks as well as scripting languages. Like C++, you only pay for features that you need. The power of Spirit comes from its modularity and extensibility. Instead of giving you a sledgehammer, it gives you the right ingredients to easily create a sledgehammer.

New Ideas: Spirit V2

Just before the development of Spirit V2 began, Hartmut came across the StringTemplate library that is a part of the ANTLR parser framework. [1] The concepts presented in that library lead Hartmut to the next step in the evolution of Spirit. Parsing and generation are tightly connected to a formal notation, or a grammar. The grammar describes both input and output, and therefore, a parser library should have a grammar driven output. This duality is expressed in Spirit by the parser library *Spirit.Qi* and the generator library *Spirit.Karma* using the same component infastructure.

[1] Quote from http:*/www.stringtemplate.org*: It is a Java template engine (with ports for C# and Python) for generating source code, web pages, emails, or any other formatted text output.

The idea of creating a lexer library well integrated with the Spirit parsers is not new. This has been discussed almost since Classic-Spirit (pre V2) initially debuted. Several attempts to integrate existing lexer libraries and frameworks with Spirit have been made and served as a proof of concept and usability (for example see Wave: The Boost C/C++ Preprocessor Library, and SLex: a fully dynamic C++ lexer implemented with Spirit). Based on these experiences we added *Spirit.Lex*: a fully integrated lexer library to the mix, allowing the user to take advantage of the power of regular expressions for token matching, removing pressure from the parser components, simplifying parser grammars. Again, Spirit's modular structure allowed us to reuse the same underlying component library as for the parser and generator libraries.

How to use this manual

Each major section (there are 3: Qi, Karma, and Lex) is roughly divided into 3 parts:

1. Tutorials: A step by step guide with heavily annotated code. These are meant to get the user acquainted with the library as quickly as possible. The objective is to build the confidence of the user in using the library through abundant examples and detailed instructions. Examples speak volumes and we have volumes of examples!

2. Abstracts: A high level summary of key topics. The objective is to give the user a high level view of the library, the key concepts, background and theories.

3. Reference: Detailed formal technical reference. We start with a quick reference -- an easy to use table that maps into the reference proper. The reference proper starts with C++ concepts followed by models of the concepts.

Some icons are used to mark certain topics indicative of their relevance. These icons precede some text to indicate:

Table 1. Icons

Icon	Name	Meaning
	Note	Generally useful information (an aside that doesn't fit in the flow of the text)
	Tip	Suggestion on how to do something (especially something that is not obvious)
	Important	Important note on something to take particular notice of
	Caution	Take special care with this - it may not be what you expect and may cause bad results
	Danger	This is likely to cause serious trouble if ignored

This documentation is automatically generated by Boost QuickBook documentation tool. QuickBook can be found in the Boost Tools.

Support

Please direct all questions to Spirit's mailing list. You can subscribe to the Spirit General List. The mailing list has a searchable archive. A search link to this archive is provided in Spirit's home page. You may also read and post messages to the mailing list through Spirit General NNTP news portal (thanks to Gmane). The news group mirrors the mailing list. Here is a link to the archives: http://news.gmane.org/gmane.comp.parsers.spirit.general.

What's New

Spirit Classic

The Spirit V1.8.x code base has been integrated with Spirit V2. It is now called *Spirit.Classic*. Since the directory structure has changed (the Spirit Classic headers are now moved to the $BOOST_ROOT/boost/spirit/home/classic directory), we created forwarding headers allowing existing applications to compile without any change. However, these forwarding headers are deprecated, which will result in corresponding warnings generated for each of the headers starting with Boost V1.38. The forwarding headers are expected to be removed in the future.

The recommended way of using Spirit Classic now is to include header files from the directory $BOOST_ROOT/boost/spirit/include. All Spirit Classic headers in this directory have 'classic_' prefixed to their name. For example the include

```
#include <boost/spirit/core/core.hpp>
```

now should be written as:

```
#include <boost/spirit/include/classic_core.hpp>
```

To avoid namespace conflicts with the new Spirit V2 library we moved Spirit Classic into the namespace `boost::spirit::classic`. All references to the former namespace `boost::spirit` need to be adjusted as soon as the header names are corrected as described above. As an alternative you can define the preprocessor constant `BOOST_SPIRIT_USE_OLD_NAMESPACE`, which will force the Spirit Classic code to be in the namespace `boost::spirit` as before. This is not recommended, though, as it may result in naming clashes.

The change of the namespace will be automatically deactivated whenever the deprecated include files are being used. This ensures full backwards compatibility for existing applications.

Spirit V2.1

What's changed in *Spirit.Qi* and *Spirit.Karma* from V2.0 (Boost V1.37.0) to 2.1 (Boost V1.41.0)

- Spirit is now based on the newest version of Boost.Proto
- `qi::phrase_parse`, `qi::phrase_format` now post-skip by default.
- `karma::generate_delimited` and `karma::format_delimited` now don't do pre- delimiting by default.
- Changed parameter sequence of `qi::phrase_parse`, `qi::phrase_match`, `karma::generate_delimited`, and `match_delimited`. The attribute is now always the last parameter.
- Added new overloads of those functions allowing to explicitely specify the post-skipping and pre-delimiting behavior.
- Added multi attribute API functions
- Removed `grammar_def<>`
- Removed functions `make_parser()` and `make_generator()`
- Removed `qi::none` and `karma::none`
- Sequences and lists now accept a standard container as their attribute
- The string placeholder terminal now can take other strings as its parameter (i.e. std::string)
- All terminals taking literals now accept a (lazy) function object as well

- All placeholders for terminals and directives (such as `int_`, `double_`, `verbatim`, etc.) were previously defined in the namespace `boost::spirit` only. Now these are additionally imported into the namespaces `spirit::qi`, `spirit::karma`, and `spirit::lex` (if they are supported by the corresponding sub-library).
- The terminal placeholders `char_` and `string` are not defined in the namespace `boost::spirit` anymore as they have been moved to the character set namespaces, allowing to do proper character set handling based on the used namespace (as `spirit::ascii`, etc.)
- The `uint`, `ushort`, `ulong`, and `byte` terminal placeholders have been renamed to `uint_`, `ushort_`, `ulong_`, and `byte_`.
- `qi::skip[]` now re-enables outer skipper if used inside `lexeme[]`
- Added `karma::maxwidth[]` directive (see `maxwidth`)
- Added `karma::omit[]` allowing to consume the attribute of subject generator without emitting any output (see `omit`).
- Added `karma::buffer[]` allowing to avoid unwanted output to be generated in case of a generator failing in the middle of a sequence (see `buffer`).
- `karma::delimit[]` now re-enables outer delimiter if used inside `verbatim[]`
- Karma: added and-predicate (`operator&()`) and not-predicate (`operator!()`) Both now always consume an attribute.
- Karma: changed semantics of `char_()`, `string()`, `int_()` et.al., and `double_()` et.al.: all of these generators now always expose an attribute. If they do not have an associated attribute, they generate their immediate literal. If they have an associated attribute, the generators first test if the attribute value is equal to the immediate literal. They fail and do not generate anything if those are not equal. Otherwise they generate their immediate literal. For more information see for instance `int_`.
- `karma::lit()` can now be used to generate integer and floating point numbers
- `qi::rule` and `karma::rule` now can be directly initialized using their copy constructor. I.e. this works now: `qi::rule<...> r = ...some parser...;`.
- Added `qi::attr()` exposing its immediate parameter as its attribute.
- Added boolean parsers and generators (`bool_`, `true_`, `false_`).
- Added `attr_cast<>` enabling in place attribute type conversion in Qi and Karma grammars.
- Almost all Karma generators now accept `optional<>` attributes and will fail generating if this is not initialized.
- Qi and Karma rules now automatically detect whether to apply auto-rule semantics or not (no need for using `operator%=()` anymore, even if it's still existing). Auto-rule semantics are applied if the right hand side has no semantic actions attached to any of the elements. This works for rule initialization and assignment.
- Qi and Karma rules now do intrinsic attribute transformation based on the attribute customization point `transform_attribute`.

What's changed in *Spirit.Lex* from V2.0 (Boost V1.37.0) to 2.1 (Boost V1.41.0)

Here is a list of changes in *Spirit.Lex* since version 2.0. *Spirit.Lex* 2.1 is a complete rewrite of the *Spirit.Lex* distributed with Boost V1.37. As with all code portions of the Spirit library, *Spirit.Lex* is usable as standalone piece. *Spirit.Lex* now uses the infrastructure provided by Spirit version 2.1.

- The lex::lexer_def class has been renamed to lex::lexer, while the original class lex::lexer does not exist anymore. This simplifies the creation of lexers.
- The lex::lexer class does not have the function `def(Self& self)` anymore, token definitions can be added to the lexer at any time, usually in the constructor of the user defined lexer class:

```
template <typename Lexer>
struct example_tokens : lex::lexer<Lexer>
{
      example_tokens()
      {
          // your token definitions here
          this->self = ...
      }
};
```

- The new lexer class can now be used directly. The function `make_lexer()` has been removed.
- The `lex::tokenize_and_parse()` and `lex::tokenize_and_phrase_parse()` functions have been changed to match the parameter sequence as implemented by the `qi::parse()` and `qi::phrase_parse()` functions. Both take an arbitrary number of attribute arguments as the last parameters. This argument list is limited by the macro `SPIRIT_ARGUMENTS_LIMIT`.
- The `lex::lexertl_lexer`, and `lex::lexertl_token` classes have been moved to the `lex::lexertl` namespace and the names have been changed to `lex::lexertl::lexer`, `lex::lexertl::token`. This also applies to the `lex::lexert_actor_lexer`, and the `static_lexertl_*` family of types.
- The class `lex::lexertl_token_set` has been removed. This functionality is now available from the lexer class.
- The *Spirit.Lex* library has been updated to use the newest version of Ben Hansons Lexertl lexer construction library (Boost review pending).
- The `lex::lexer<Lexer>` template constructor now takes an optional parameter specifying the `match_flags` to be used for table generation. Currently, there are the following flags available:

  ```
  match_flags::match_default,          // no flags
  match_flags::match_not_dot_newline,  // the regex '.' doesn't match newlines
  match_flags::match_icase             // all matching operations are case insensitive
  ```

  If no parameter is passed to the constructor, `match_flags::match_default` is used, i.e. the `.` matches newlines and matching is case sensitive.
- The `char_()` and `string()` placeholders can now be used for token definitions and are synonymous with `token_def`.
- Lexer semantic actions now have to conform to a changed interface (see Lexer Semantic Actions for details).
- Added placeholder symbols usable from the inside of lexer semantic actions while using Phoenix: `lex::_start`, `lex::_end`, `lex::_eoi`, `lex::_state`, `lex::_val`, and `lex::_pass` (see Lexer Semantic Actions for more details).
- Added (lazy) support functions usable from the inside of lexer semantic actions while using Phoenix: `lex::more()`, `lex::less()`, and `lex::lookahead()` (see Lexer Semantic Actions for more details).
- Removed `lex::omitted` in favor of `lex::omit` to unify the overall interface.

Introduction

Boost Spirit is an object-oriented, recursive-descent parser and output generation library for C++. It allows you to write grammars and format descriptions using a format similar to Extended Backus Naur Form (EBNF) [2] directly in C++. These inline grammar specifications can mix freely with other C++ code and, thanks to the generative power of C++ templates, are immediately executable. In retrospect, conventional compiler-compilers or parser-generators have to perform an additional translation step from the source EBNF code to C or C++ code.

[2] ISO-EBNF

The syntax and semantics of the libraries' API directly form domain-specific embedded languages (DSEL). In fact, Spirit exposes 3 different DSELs to the user:

- one for creating parser grammars,
- one for the specification of the required tokens to be used for parsing,
- and one for the description of the required output formats.

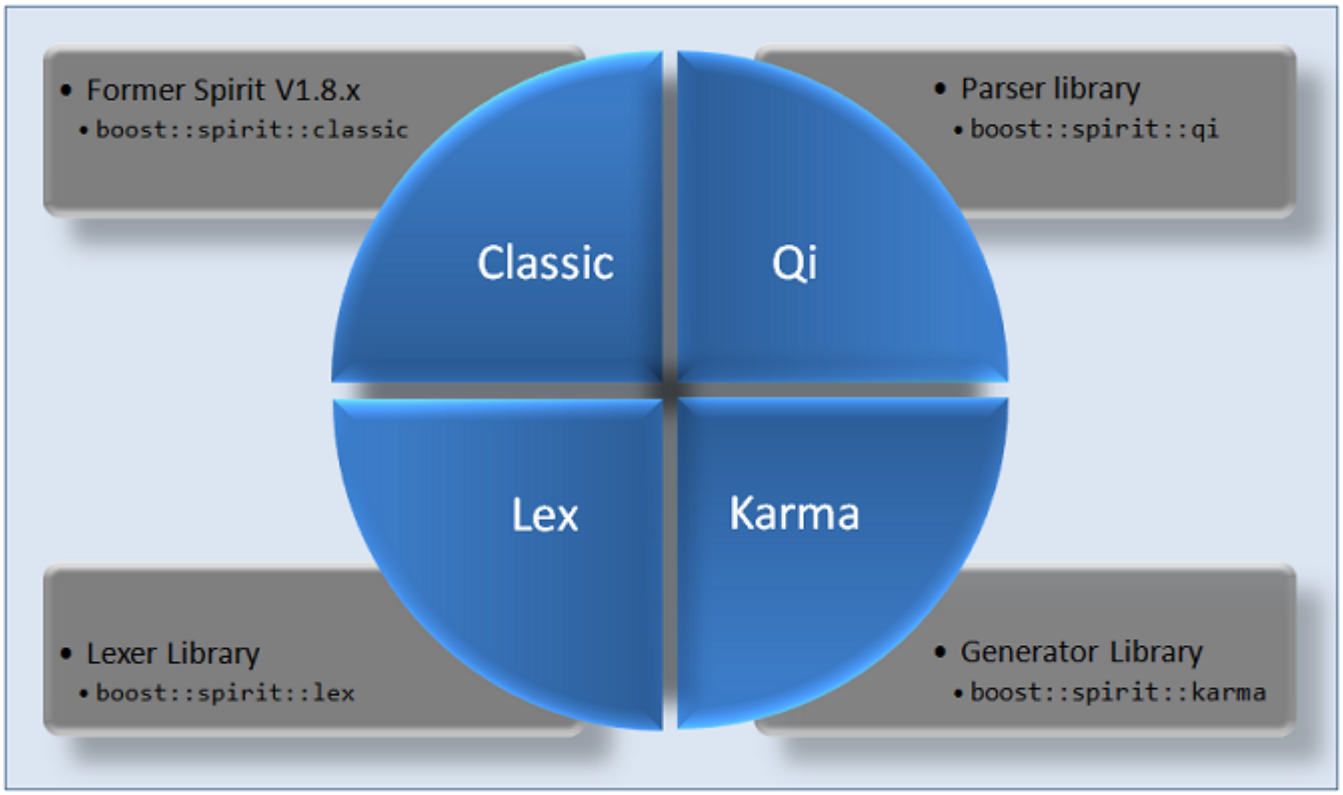
Since the target input grammars and output formats are written entirely in C++ we do not need any separate tools to compile, preprocess or integrate those into the build process. Spirit allows seamless integration of the parsing and output generation process with other C++ code. This often allows for simpler and more efficient code.

Both the created parsers and generators are fully attributed, which allows you to easily build and handle hierarchical data structures in memory. These data structures resemble the structure of the input data and can directly be used to generate arbitrarily-formatted output.

The figure below depicts the overall structure of the Boost Spirit library. The library consists of 4 major parts:

- *Spirit.Classic*: This is the almost-unchanged code base taken from the former Boost Spirit V1.8 distribution. It has been moved into the namespace boost::spirit::classic. A special compatibility layer has been added to ensure complete compatibility with existing code using Spirit V1.8.
- *Spirit.Qi*: This is the parser library allowing you to build recursive descent parsers. The exposed domain-specific language can be used to describe the grammars to implement, and the rules for storing the parsed information.
- *Spirit.Lex*: This is the library usable to create tokenizers (lexers). The domain-specific language exposed by *Spirit.Lex* allows you to define regular expressions used to match tokens (create token definitions), associate these regular expressions with code to be executed whenever they are matched, and to add the token definitions to the lexical analyzer.
- *Spirit.Karma*: This is the generator library allowing you to create code for recursive descent, data type-driven output formatting. The exposed domain-specific language is almost equivalent to the parser description language used in *Spirit.Qi*, except that it is used to describe the required output format to generate from a given data structure.

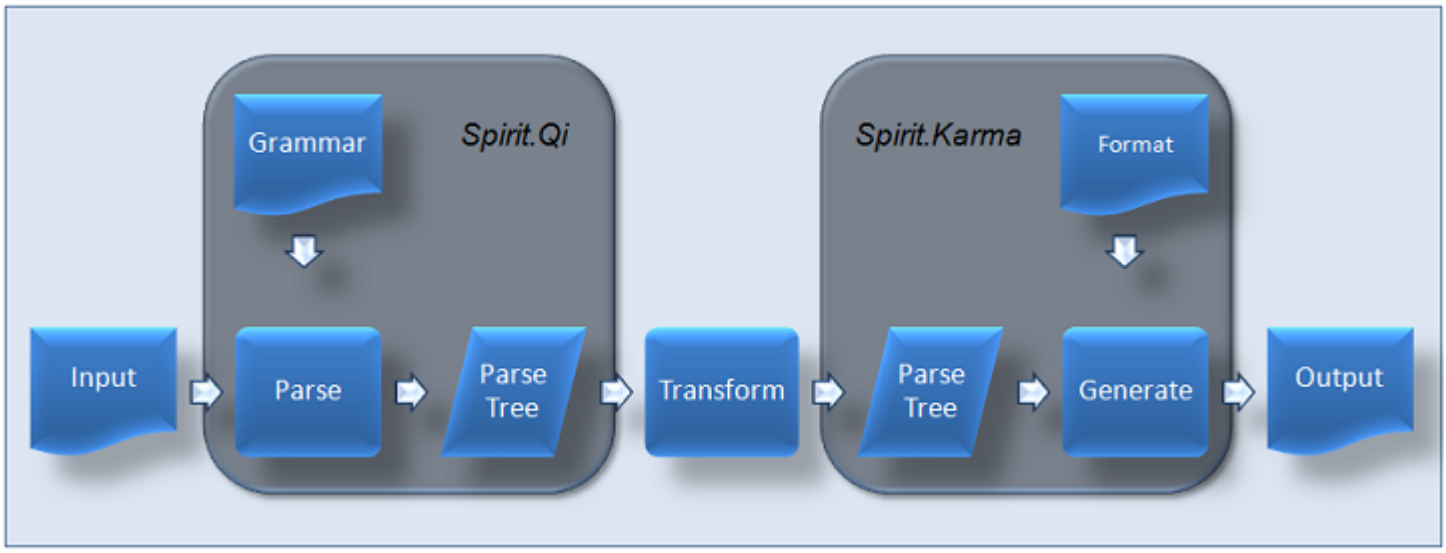
Figure 1. The overall structure of the Boost Spirit library



The three components, *Spirit.Qi*, *Spirit.Karma* and *Spirit.Lex*, are designed to be used either standalone, or together. The general methodology is to use the token sequence generated by *Spirit.Lex* as the input for a parser generated by *Spirit.Qi*. On the opposite side of the equation, the hierarchical data structures generated by *Spirit.Qi* are used for the output generators created using *Spirit.Karma*. However, there is nothing to stop you from using any of these components all by themselves.

The figure below shows the typical data flow of some input being converted to some internal representation. After some (optional) transformation these data are converted back into some different, external representation. The picture highlights Spirit's place in this data transformation flow.

Figure 2. The place of *Spirit.Qi* and *Spirit.Karma* in a data transformation flow of a typical application



A Quick Overview of Parsing with *Spirit.Qi*

Spirit.Qi is Spirit's sublibrary dealing with generating parsers based on a given target grammar (essentially a format description of the input data to read).

A simple EBNF grammar snippet:

```
group       ::= '(' expression ')'
factor      ::= integer | group
term        ::= factor (('*' factor) | ('/' factor))*
expression  ::= term (('+' term) | ('-' term))*
```

is approximated using facilities of Spirit's *Qi* sublibrary as seen in this code snippet:

```
group       = '(' >> expression >> ')';
factor      = integer | group;
term        = factor >> *(('*' >> factor) | ('/' >> factor));
expression  = term >> *(('+' >> term) | ('-' >> term));
```

Through the magic of expression templates, this is perfectly valid and executable C++ code. The production rule `expression` is, in fact, an object that has a member function `parse` that does the work given a source code written in the grammar that we have just declared. Yes, it's a calculator. We shall simplify for now by skipping the type declarations and the definition of the rule `integer` invoked by `factor`. Now, the production rule `expression` in our grammar specification, traditionally called the `start` symbol, can recognize inputs such as:

```
12345
-12345
+12345
1 + 2
1 * 2
1/2 + 3/4
1 + 2 + 3 + 4
1 * 2 * 3 * 4
(1 + 2) * (3 + 4)
(-1 + 2) * (3 + -4)
1 + ((6 * 200) - 20) / 6
(1 + (2 + (3 + (4 + 5))))
```

Certainly we have modified the original EBNF syntax. This is done to conform to C++ syntax rules. Most notably we see the abundance of shift >> operators. Since there are no 'empty' operators in C++, it is simply not possible to write something like:

```
a b
```

as seen in math syntax, for example, to mean multiplication or, in our case, as seen in EBNF syntax to mean sequencing (b should follow a). *Spirit.Qi* uses the shift >> operator instead for this purpose. We take the >> operator, with arrows pointing to the right, to mean "is followed by". Thus we write:

```
a >> b
```

The alternative operator `|` and the parentheses `()` remain as is. The assignment operator `=` is used in place of EBNF's `::=`. Last but not least, the Kleene star `*`, which in this case is a postfix operator in EBNF becomes a prefix. Instead of:

```
a* //... in EBNF syntax,
```

we write:

```
*a //... in Spirit.
```

since there are no postfix stars, `*`, in C/C++. Finally, we terminate each rule with the ubiquitous semi-colon, `;`.

A Quick Overview of Output Generation with *Spirit.Karma*

Spirit not only allows you to describe the structure of the input, it also enables the specification of the output format for your data in a similar way, and based on a single syntax and compatible semantics.

Let's assume we need to generate a textual representation from a simple data structure such as a `std::vector<int>`. Conventional code probably would look like:

```
std::vector<int> v (initialize_and_fill());
std::vector<int>::iterator end = v.end();
for (std::vector<int>::iterator it = v.begin(); it != end; ++it)
    std::cout << *it << std::endl;
```

which is not very flexible and quite difficult to maintain when it comes to changing the required output format. Spirit's sublibrary *Karma* allows you to specify output formats for arbitrary data structures in a very flexible way. The following snippet is the *Karma* format description used to create the same output as the traditional code above:

```
*(int_ << eol)
```

Here are some more examples of format descriptions for different output representations of the same `std::vector<int>`:

Table 2. Different output formats for `std::vector<int>`

Format	Example	Description
`'[' << *(int_ << ',') << ']'`	`[1,8,10,]`	Comma separated list of integers
`*('(' << int_ << ')' << ',')`	`(1),(8),(10),`	Comma separated list of integers in parenthesis
`*hex`	`18a`	A list of hexadecimal numbers
`*(double_ << ',')`	`1.0,8.0,10.0,`	A list of floating point numbers

We will see later in this documentation how it is possible to avoid printing the trailing `','`.

Overall, the syntax is similar to *Spirit.Qi* with the exception that we use the `<<` operator for output concatenation. This should be easy to understand as it follows the conventions used in the Standard's I/O streams.

Another important feature of *Spirit.Karma* allows you to fully decouple the data type from the output format. You can use the same output format with different data types as long as these conform conceptually. The next table gives some related examples.

Table 3. Different data types usable with the output format `*(int_ << eol)`

Data type	Description
`int i[4]`	C style arrays
`std::vector<int>`	Standard vector
`std::list<int>`	Standard list
`boost::array<long, 20>`	Boost array

Structure

Include

Spirit is a header file only library. There are no libraries to link to. This section documents the structure of the Spirit headers.

Spirit contains five sub-libraries plus a 'support' module where common support classes are placed:

- Classic
- Qi
- Karma
- Lex
- Phoenix
- Support

The top Spirit directory is:

```
BOOST_ROOT/boost/spirit
```

Currently, the directory contains:

```
[actor]     [attribute]     [core]      [debug]
[dynamic]   [error_handling][home]      [include]
[iterator]  [meta]          [phoenix]   [repository]
[symbols]   [tree]          [utility]
```

These include some old v1.8 directories that are now depracated. These are: actor, attribute, core, debug, dynamic, error_handling, iterator, meta, phoenix, symbols, tree and utility. There is no guarantee that these directories will still be present in future versions of Spirit. We only keep them for backward compatibility. Please be warned.

Each directory (except include, home, and repository) has a corresponding header file that contains forwarding includes of each relevant include file that the directory contains. For example, there exists a <boost/spirit/actor.hpp> header file which includes all the relevant files from the boost/spirit/actor directory.

To distinguish between Spirit versions, you can inspect the version file:

```
<boost/spirit/version.hpp>
```

using the preprocessor define

```
SPIRIT_VERSION
```

It is a hex number where the first two digits determine the major version while the last two digits determine the minor version. For example:

```
#define SPIRIT_VERSION 0x2010 // version 2.1
```

The include directory at:

```
BOOST_ROOT/boost/spirit/include
```

is a special flat directory that contains all the Spirit headers. To accomodate the flat structure, the headers are prefixed with the sub-library name:

- classic_
- karma_
- lex_
- phoenix1_
- phoenix_
- qi_
- support_

For example, if you used to include <boost/spirit/actor.hpp>, which is now a deprecated header, you should instead include <boost/spirit/include/classic_actor.hpp>

If you want to simply include the main sub-library name, then you can include:

- <boost/spirit/include/classic.hpp>
- <boost/spirit/include/karma.hpp>
- <boost/spirit/include/lex.hpp>
- <boost/spirit/include/phoenix1.hpp>
- <boost/spirit/include/phoenix.hpp>
- <boost/spirit/include/qi.hpp>
- <boost/spirit/include/support.hpp>

The home directory:

```
BOOST_ROOT/boost/spirit/home
```

is the *real* home of Spirit. It is the place where the various sub-libraries actually exist. The home directory contains:

```
[classic]   [karma]     [lex]
[phoenix]   [qi]        [support]
```

As usual, these directories have their corresponding include files:

- <boost/spirit/home/classic.hpp>
- <boost/spirit/home/karma.hpp>
- <boost/spirit/home/lex.hpp>
- <boost/spirit/home/phoenix.hpp>
- <boost/spirit/home/qi.hpp>
- <boost/spirit/home/support.hpp>

The various sub-libraries include files can be found in each sub-directory containing the particular sub-library. The include structure of a sub-library is covered in its documentation. For consistency, each library follows the same scheme as above.

To keep it simple, you should use the flat include directory at boost/spirit/include.

For some additional information about the rationale you might want to have a look at the FAQ entry Header Hell.

The subdirectory `boost/spirit/repository` does not belong to the main Spirit distribution. For more information please refer to: Spirit Repository.

Abstracts

Syntax Diagram

In the next section, we will deal with Parsing Expression Grammars (PEG) [3] , a variant of Extended Backus-Naur Form (EBNF) [4] with a different interpretation. It is easier to understand PEG using Syntax Diagrams. Syntax diagrams represent a grammar graphically. It was used extensibly by Niklaus Wirth [5] in the "Pascal User Manual". Syntax Diagrams are easily understandable by programmers due to their similarity to flow charts. The isomorphism of the diagrams and functions make them ideal for representing Recursive Descent parsers which are essentially mutually recursive functions.

Historically, Parsing Expression Grammars have been used for describing grammars for parsers only (hence the name). In Spirit we use a very similar notation for output generation as well. Almost all the concepts described here are equally applicable both to *Spirit.Qi* parsers and to *Spirit.Karma* generators.

Elements

All diagrams have one entry and one exit point. Arrows connect all possible paths through the grammar from the entry point to the exit point.

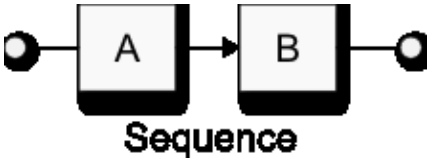
Terminals are represented by round boxes. Terminals are atomic and usually represent plain characters, strings or tokens.

Non-terminals are represented by boxes. Diagrams are modularized using named non-terminals. A complex diagram can be broken down into a set of non-terminals. Non-terminals also allow recursion (i.e. a non-terminal can call itself).

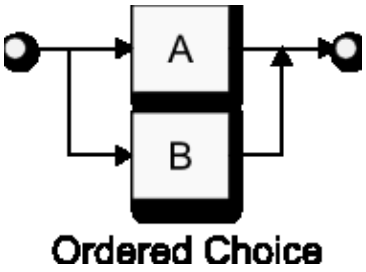
[3] Bryan Ford: Parsing Expression Grammars: A Recognition-Based Syntactic Foundation, http://pdos.csail.mit.edu/~baford/packrat/popl04/
[4] Richard E. Pattis: EBNF: A Notation to Describe Syntax, http://www.cs.cmu.edu/~pattis/misc/ebnf.pdf
[5] Niklaus Wirth: The Programming Language Pascal. (July 1973)

Constructs

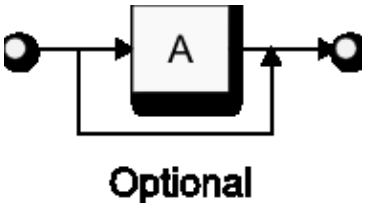
The most basic composition is the Sequence. B follows A:



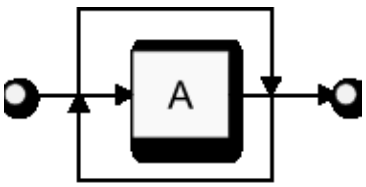
The ordered choice henceforth we will call *alternatives*. In PEG, ordered choice and alternatives are not quite the same. PEG allows ambiguity of choice where one or more branches can succeed. In PEG, in case of ambiguity, the first one always wins.

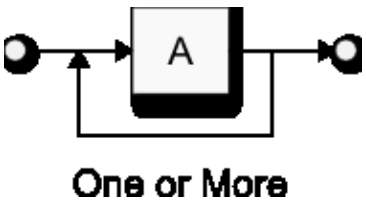


The optional (zero-or-one):



Now, the loops. We have the zero-or-more and one-or-more:





Take note that, as in PEG, these loops behave greedily. If there is another 'A' just before the end-point, it will always fail because the preceding loop has already exhausted all 'A's and there is nothing more left. This is a crucial difference between PEG and general Context Free Grammars (CFGs). This behavior is quite obvious with syntax diagrams as they resemble flow-charts.

Predicates

Now, the following are Syntax Diagram versions of PEG predicates. These are not traditionally found in Syntax Diagrams. These are special extensions we invented to closely follow PEGs.

First, we introduce a new element, the Predicate:

This is similar to the conditionals in flow charts where the 'No' branch is absent and always signals a failed parse.

We have two versions of the predicate, the *And-Predicate* and the *Not-Predicate*:

The *And-Predicate* tries the predicate, P, and succeeds if P succeeds, or otherwise fail. The opposite is true with the *Not-Predicate*. It tries the predicate, P, and fails if P succeeds, or otherwise succeeds. Both versions do a look-ahead but do not consume any input regardless if P succeeds or not.

Parsing Expression Grammar

Parsing Expression Grammars (PEG) [6] are a derivative of Extended Backus-Naur Form (EBNF) [7] with a different interpretation, designed to represent a recursive descent parser. A PEG can be directly represented as a recursive-descent parser.

Like EBNF, PEG is a formal grammar for describing a formal language in terms of a set of rules used to recognize strings of this language. Unlike EBNF, PEGs have an exact interpretation. There is only one valid parse tree (see Abstract Syntax Tree) for each PEG grammar.

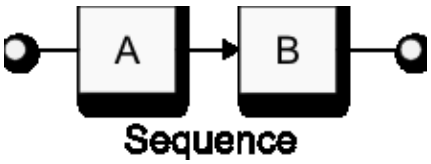
Sequences

Sequences are represented by juxtaposition like in EBNF:

```
a b
```

The PEG expression above states that, in order for this to succeed, `b` must follow `a`. Here's the syntax diagram:

[6] Bryan Ford: Parsing Expression Grammars: A Recognition-Based Syntactic Foundation, http://pdos.csail.mit.edu/~baford/packrat/popl04/
[7] Richard E. Pattis: EBNF: A Notation to Describe Syntax, http://www.cs.cmu.edu/~pattis/misc/ebnf.pdf



Here's a trivial example:

```
'x' digit
```

which means the character x must be followed by a digit.

Note

In *Spirit.Qi*, we use the >> for sequences since C++ does not allow juxtaposition, while in *Spirit.Karma* we use the << instead.

Alternatives

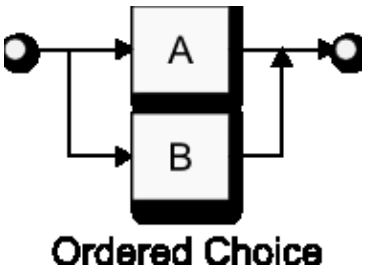
Alternatives are represented in PEG using the slash:

```
a / b
```

Note

In *Spirit.Qi* and *Spirit.Karma*, we use the | for alternatives just as in EBNF.

Alternatives allow for choices. The expression above reads: try to match a. If a succeeds, success, if not try to match b. This is a bit of a deviation from the usual EBNF interpretation where you simply match a **or** b. Here's the syntax diagram:



PEGs allow for ambiguity in the alternatives. In the expression above, both a or b can both match an input string. However, only the first matching alternative is valid. As noted, there can only be one valid parse tree.

Loops

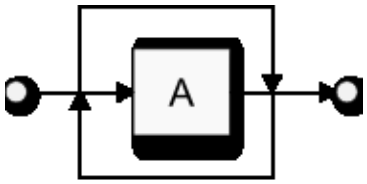
Again, like EBNF, PEG uses the regular-expression Kleene star and the plus loops:

```
a*
a+
```

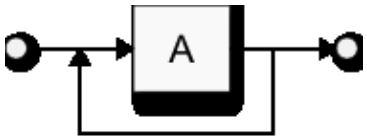
Note

Spirit.Qi and *Spirit.Karma* use the prefix star and plus since there is no postfix star or plus in C++.

Here are the syntax diagrams:



Zero or More



One or More

The first, called the Kleene star, matches zero or more of its subject `a`. The second, plus, matches one ore more of its subject `a`.

Unlike EBNF, PEGs have greedy loops. It will match as much as it can until its subject fails to match without regard to what follows. The following is a classic example of a fairly common EBNF/regex expression failing to match in PEG:

```
alnum* digit
```

In PEG, alnum will eat as much alpha-numeric characters as it can leaving nothing more left behind. Thus, the trailing digit will get nothing. Loops are simply implemented in recursive descent code as for/while loops making them extremely efficient. That is a definite advantage. On the other hand, those who are familiar with EBNF and regex behavior might find the behavior a major gotcha. PEG provides a couple of other mechanisms to circumvent this. We will see more of these other mechanisms shortly.

Difference

In some cases, you may want to restrict a certain expression. You can think of a PEG expression as a match for a potentially infinite set of strings. The difference operator allows you to restrict this set:

```
a - b
```

The expression reads: match `a` but not `b`.

Note

There is no difference operator in *Spirit.Karma*, as the concept does not make sense in the context of output generation.

Attributes

Attributes of Primitive Components

Parsers and generators in Spirit are fully attributed. *Spirit.Qi* parsers always *expose* an attribute specific to their type. This is called *synthesized attribute* as it is returned from a successful match representing the matched input sequence. For instance, numeric parsers, such as `int_` or `double_`, return the `int` or `double` value converted from the matched input sequence. Other primitive parser components have other intuitive attribute types, such as for instance `int_` which has `int`, or `ascii::char_` which has `char`. Forprimitive parsers apply the normal C++ convertibility rules: you can use any Other primitive parser components have other intuitive attribute types, e.g. the parser `ascii::char_` has `char` as attribute type. For primitive parsers the normal C++ convertibility rules apply: you can use any C++ type to receive the parsed value as long as the attribute type of the parser is convertible to the type

provided. The following example shows how a synthesized parser attribute (the `int` value) is extracted by calling the API function `qi::parse`:

```
int value = 0;
std::string str("123");
qi::parse(str.begin(), str.end(), int_, value);   // value == 123
```

The attribute type of a generator defines what data types this generator is able to consume in order to produce its output. *Spirit.Karma* generators always *expect* an attribute specific to their type. This is called *consumed attribute* and is expected to be passed to the generator. The consumed attribute is most of the time the value the generator is designed to emit output for. For primitive generators the normal C++ convertibility rules apply. Any data type convertible to the attribute type of a primitive generator can be used to provide the data to generate. We present a similar example as above, this time the consumed attribute of the `int_` generator (the `int` value) is passed to the API function `karma::generate`:

```
int value = 123;
std::string str;
std::back_insert_iterator<std::string> out(str);
karma::generate(out, int_, value);                // str == "123"
```

Other primitive generator components have other intuitive attribute types, very similar to the corresponding parser components. For instance, the `ascii::char_` generator has `char` as consumed attribute. For a full list of available parser and generator primitives and their attribute types please see the sections Qi Parsers and Karma Generators.

Attributes of Compound Components

Spirit.Qi and *Spirit.Karma* implement well defined attribute type propagation rules for all compound parsers and generators, such as sequences, alternatives, Kleene star, etc. The main attribute propagation rule for a sequences is for instance:

Library	Sequence attribute propagation rule
Qi	`a: A, b: B --> (a >> b): tuple<A, B>`
Karma	`a: A, b: B --> (a << b): tuple<A, B>`

which reads as:

> Given `a` and `b` are parsers (generators), and `A` is the attribute type of `a`, and `B` is the attribute type of `b`, then the attribute type of `a >> b` (`a << b`) will be `tuple<A, B>`.

Note

The notation `tuple<A, B>` is used as a placeholder expression for any fusion sequence holding the types A and B, such as `boost::fusion::tuple<A, B>` or `std::pair<A, B>` (for more information see Boost.Fusion).

As you can see, in order for a type to be compatible with the attribute type of a compound expression it has to

- either be convertible to the attribute type,
- or it has to expose certain functionalities, i.e. it needs to conform to a concept compatible with the component.

Each compound component implements its own set of attribute propagation rules. For a full list of how the different compound generators consume attributes see the sections Parser Compound Attribute Rules and Generator Compound Attribute Rules.

The Attribute of Sequence Parsers and Generators

Sequences require an attribute type to expose the concept of a fusion sequence, where all elements of that fusion sequence have to be compatible with the corresponding element of the component sequence. For example, the expression:

Library	Sequence expression
Qi	`double_ >> double_`
Karma	`double_ << double_`

is compatible with any fusion sequence holding two types, where both types have to be compatible with `double`. The first element of the fusion sequence has to be compatible with the attribute of the first `double_`, and the second element of the fusion sequence has to be compatible with the attribute of the second `double_`. If we assume to have an instance of a `std::pair<double, double>`, we can directly use the expressions above to do both, parse input to fill the attribute:

```
// the following parses "1.0 2.0" into a pair of double
std::string input("1.0 2.0");
std::pair<double, double> p;
qi::phrase_parse(input.begin(), input.end(),
    qi::double_ >> qi::double_,       // parser grammar
    qi::space,                        // delimiter grammar
    p);                               // attribute to fill while parsing
```

and generate output for it:

```
// the following generates: "1.0 2.0" from the pair filled above
std::string str;
std::back_insert_iterator<std::string> out(str);
karma::generate_delimited(out,
    karma::double_ << karma::double_, // generator grammar (format description)
    karma::space,                     // delimiter grammar
    p);                               // data to use as the attribute
```

(where the `karma::space` generator is used as the delimiter, allowing to automatically skip/insert delimiting spaces in between all primitives).

Tip

For sequences only: *Spirit.Qi* and *Spirit.Karma* expose a set of API functions usable mainly with sequences. Very much like the functions of the `scanf` and `printf` families these functions allow to pass the attributes for each of the elements of the sequence separately. Using the corresponding overload of *Qi's* parse or *Karma's* `generate()` the expression above could be rewritten as:

```
double d1 = 0.0, d2 = 0.0;
qi::phrase_parse(begin, end, qi::double_ >> qi::double_, qi::space, d1, d2);
karma::generate_delim↵
ited(out, karma::double_ << karma::double_, karma::space, d1, d2);
```

where the first attribute is used for the first `double_`, and the second attribute is used for the second `double_`.

The Attribute of Alternative Parsers and Generators

Alternative parsers and generators are all about - well - alternatives. In order to store possibly different result (attribute) types from the different alternatives we use the data type Boost.Variant. The main attribute propagation rule of these components is:

```
a: A, b: B --> (a | b): variant<A, B>
```

Alternatives have a second very important attribute propagation rule:

```
a: A, b: A --> (a | b): A
```

often allowing to simplify things significantly. If all sub expressions of an alternative expose the same attribute type, the overall alternative will expose exactly the same attribute type as well.

More About Attributes of Compound Components

While parsing input or generating output it is often desirable to combine some constant elements with variable parts. For instance, let us look at the example of parsing or formatting a complex number, which is written as `(real, imag)`, where `real` and `imag` are the variables representing the real and imaginary parts of our complex number. This can be achieved by writing:

Library	**Sequence expression**
Qi	`'(' >> double_ >> ", " >> double_ >> ')'`
Karma	`'(' << double_ << ", " << double_ << ')'`

Fortunately, literals (such as `'('` and `", "`) do *not* expose any attribute (well actually, they do expose the special type `unused_type`, but in this context `unused_type` is interpreted as if the component does not expose any attribute at all). It is very important to understand that the literals don't consume any of the elements of a fusion sequence passed to this component sequence. As said, they just don't expose any attribute and don't produce (consume) any data. The following example shows this:

```
// the following parses "(1.0, 2.0)" into a pair of double
std::string input("(1.0, 2.0)");
std::pair<double, double> p;
qi::parse(input.begin(), input.end(),
    '(' >> qi::double_ >> ", " >> qi::double_ >> ')', // parser grammar
    p);                                               // attribute to fill while parsing
```

and here is the equivalent *Spirit.Karma* code snippet:

```
// the following generates: (1.0, 2.0)
std::string str;
std::back_insert_iterator<std::string> out(str);
generate(out,
    '(' << karma::double_ << ", " << karma::double_ << ')', // generator grammar (format descrip↵
tion)
    p);                                                     // data to use as the attribute
```

where the first element of the pair passed in as the data to generate is still associated with the first `double_`, and the second element is associated with the second `double_` generator.

This behavior should be familiar as it conforms to the way other input and output formatting libraries such as `scanf`, `printf` or `boost::format` are handling their variable parts. In this context you can think about *Spirit.Qi*'s and *Spirit.Karma*'s primitive components (such as the `double_` above) as of being typesafe placeholders for the attribute values.

Tip

Similarly to the tip provided above, this example could be rewritten using *Spirit's* multi-attribute API function:

```
double d1 = 0.0, d2 = 0.0;
qi::parse(begin, end, '(' >> qi::double_ >> ", " >> qi::double_ << ')', d1, d2);
karma::generate(out, '(' << karma::double_ << ", " << karma::double_ << ')', d1, d2);
```

which provides a clear and comfortable syntax, more similar to the placeholder based syntax as exposed by `printf` or `boost::format`.

Let's take a look at this from a more formal perspective. The sequence attribute propagation rules define a special behavior if generators exposing `unused_type` as their attribute are involved (see Generator Compound Attribute Rules):

Library	Sequence attribute propagation rule
Qi	`a: A, b: Unused --> (a >> b): A`
Karma	`a: A, b: Unused --> (a << b): A`

which reads as:

> Given `a` and `b` are parsers (generators), and `A` is the attribute type of `a`, and `unused_type` is the attribute type of `b`, then the attribute type of `a >> b` (`a << b`) will be `A` as well. This rule applies regardless of the position the element exposing the `unused_type` is at.

This rule is the key to the understanding of the attribute handling in sequences as soon as literals are involved. It is as if elements with `unused_type` attributes 'disappeared' during attribute propagation. Notably, this is not only true for sequences but for any compound components. For instance, for alternative componets the corresponding rule is:

```
a: A, b: Unused --> (a | b): A
```

again, allowing to simplify the overall attribute type of an expression.

Attributes of Rules and Grammars

Nonterminals are well known from parsers where they are used as the main means of constructing more complex parsers out of simpler ones. The nonterminals in the parser world are very similar to functions in an imperative programming language. They can be used to encapsulate parser expressions for a particular input sequence. After being defined, the nonterminals can be used as 'normal' parsers in more complex expressions whenever the encapsulated input needs to be recognized. Parser nonterminals in *Spirit.Qi* may accept *parameters* (inherited attributes) and usually return a value (the synthesized attribute).

Both, the types of the inherited and the synthesized attributes have to be explicitely specified while defining the particular `grammar` or the `rule` (the Spirit Repository additionally has `subrules` which conform to a similar interface). As an example, the following code declares a *Spirit.Qi* `rule` exposing an `int` as its synthesized attribute, while expecting a single `double` as its inherited attribute (see the section about the *Spirit.Qi* Rule for more information):

```
qi::rule<Iterator, int(double)> r;
```

In the world of generators, nonterminals are just as useful as in the parser world. Generator nonterminals encapsulate a format description for a particular data type, and, whenever we need to emit output for this data type, the corresponding nonterminal is invoked in a similar way as the predefined *Spirit.Karma* generator primitives. The *Spirit.Karma* nonterminals are very similar to the *Spirit.Qi* nonterminals. Generator nonterminals may accept *parameters* as well, and we call those inherited attributes too. The main difference is that they do not expose a synthesized attribute (as parsers do), but they require a special *consumed attribute*. Usually the consumed

attribute is the value the generator creates its output from. Even if the consumed attribute is not 'returned' from the generator we chose to use the same function style declaration syntax as used in *Spirit.Qi*. The example below declares a *Spirit.Karma* `rule` consuming a `double` while not expecting any additional inherited attributes.

```
karma::rule<OutputIterator, double()> r;
```

The inherited attributes of nonterminal parsers and generators are normally passed to the component during its invocation. These are the *parameters* the parser or generator may accept and they can be used to parameterize the component depending on the context they are invoked from.

Qi - Writing Parsers

Tutorials

Quick Start

Why would you want to use Spirit.Qi?

Spirit.Qi is designed to be a practical parsing tool. The ability to generate a fully-working parser from a formal EBNF specification inlined in C++ significantly reduces development time. Programmers typically approach parsing using ad hoc hacks with primitive tools such as scanf. Even regular-expression libraries (such as boost regex) or scanners (such as Boost tokenizer) do not scale well when we need to write more elaborate parsers. Attempting to write even a moderately-complex parser using these tools leads to code that is hard to understand and maintain.

One prime objective is to make the tool easy to use. When one thinks of a parser generator, the usual reaction is "it must be big and complex with a steep learning curve." Not so. Spirit is designed to be fully scalable. The library is structured in layers. This permits learning on an as-needed basis, after only learning the minimal core and basic concepts.

For development simplicity and ease in deployment, the entire library consists of only header files, with no libraries to link against or build. Just put the Spirit distribution in your include path, compile and run. Code size? -very tight -essentially comparable to hand written recursive descent code.

Our tutorials will walk you through the simplest Spirit examples, incrementally building on top of the earlier examples as we expose more and more features and techniques. We will try to be as gentle as possible with the learning curve. We will present the tutorials in a cookbook style approach. This style of presentation is based on our BoostCon '07 and BoostCon '08 slides.

Have fun!

Warming up

We'll start by showing examples of parser expressions to give you a feel on how to build parsers from the simplest parser, building up as we go. When comparing EBNF to Spirit, the expressions may seem awkward at first. Spirit heavily uses operator overloading to accomplish its magic.

Trivial Example #1 Parsing a number

Create a parser that will parse a floating-point number.

```
double_
```

(You've got to admit, that's trivial!) The above code actually generates a Spirit floating point parser (a built-in parser). Spirit has many pre-defined parsers and consistent naming conventions help you keep from going insane!

Trivial Example #2 Parsing two numbers

Create a parser that will accept a line consisting of two floating-point numbers.

```
double_ >> double_
```

Here you see the familiar floating-point numeric parser `double_` used twice, once for each number. What's that >> operator doing in there? Well, they had to be separated by something, and this was chosen as the "followed by" sequence operator. The above program creates a parser from two simpler parsers, glueing them together with the sequence operator. The result is a parser that is a composition of smaller parsers. Whitespace between numbers can implicitly be consumed depending on how the parser is invoked (see below).

Note

When we combine parsers, we end up with a "bigger" parser, but it's still a parser. Parsers can get bigger and bigger, nesting more and more, but whenever you glue two parsers together, you end up with one bigger parser. This is an important concept.

Trivial Example #3 Parsing zero or more numbers

Create a parser that will accept zero or more floating-point numbers.

```
*double_
```

This is like a regular-expression Kleene Star, though the syntax might look a bit odd for a C++ programmer not used to seeing the * operator overloaded like this. Actually, if you know regular expressions it may look odd too since the star is before the expression it modifies. C'est la vie. Blame it on the fact that we must work with the syntax rules of C++.

Any expression that evaluates to a parser may be used with the Kleene Star. Keep in mind that C++ operator precedence rules may require you to put expressions in parentheses for complex expressions. The Kleene Star is also known as a Kleene Closure, but we call it the Star in most places.

Trivial Example #4 Parsing a comma-delimited list of numbers

This example will create a parser that accepts a comma-delimited list of numbers.

```
double_ >> *(char_(',') >> double_)
```

Notice `char_(',')`. It is a literal character parser that can recognize the comma `','`. In this case, the Kleene Star is modifying a more complex parser, namely, the one generated by the expression:

```
(char_(',') >> double_)
```

Note that this is a case where the parentheses are necessary. The Kleene star encloses the complete expression above.

Let's Parse!

We're done with defining the parser. So the next step is now invoking this parser to do its work. There are a couple of ways to do this. For now, we will use the `phrase_parse` function. One overload of this function accepts four arguments:

1. An iterator pointing to the start of the input
2. An iterator pointing to one past the end of the input
3. The parser object
4. Another parser called the skip parser

In our example, we wish to skip spaces and tabs. Another parser named `space` is included in Spirit's repertoire of predefined parsers. It is a very simple parser that simply recognizes whitespace. We will use `space` as our skip parser. The skip parser is the one responsible for skipping characters in between parser elements such as the `double_` and `char_`.

Ok, so now let's parse!

```
template <typename Iterator>
bool parse_numbers(Iterator first, Iterator last)
{
    using qi::double_;
    using qi::phrase_parse;
    using ascii::space;

    bool r = phrase_parse(
        first,                          ❶
        last,                           ❷
        double_ >> *(',' >> double_),   ❸
        space                           ❹
    );
    if (first != last) // fail if we did not get a full match
        return false;
    return r;
}
```

❶ start iterator
❷ end iterator
❸ the parser
❹ the skip-parser

The parse function returns `true` or `false` depending on the result of the parse. The first iterator is passed by reference. On a successful parse, this iterator is repositioned to the rightmost position consumed by the parser. If this becomes equal to `last`, then we have a full match. If not, then we have a partial match. A partial match happens when the parser is only able to parse a portion of the input.

Note that we inlined the parser directly in the call to parse. Upon calling parse, the expression evaluates into a temporary, unnamed parser which is passed into the parse() function, used, and then destroyed.

Here, we opted to make the parser generic by making it a template, parameterized by the iterator type. By doing so, it can take in data coming from any STL conforming sequence as long as the iterators conform to a forward iterator.

You can find the full cpp file here: ../../example/qi/num_list1.cpp

Note

`char` and `wchar_t` operands

The careful reader may notice that the parser expression has `','` instead of `char_(',')` as the previous examples did. This is ok due to C++ syntax rules of conversion. There are >> operators that are overloaded to accept a `char` or `wchar_t` argument on its left or right (but not both). An operator may be overloaded if at least one of its parameters is a user-defined type. In this case, the `double_` is the 2nd argument to `operator>>`, and so the proper overload of >> is used, converting `','` into a character literal parser.

The problem with omiting the `char_` should be obvious: `'a' >> 'b'` is not a spirit parser, it is a numeric expression, right-shifting the ASCII (or another encoding) value of `'a'` by the ASCII value of `'b'`. However, both `char_('a') >> 'b'` and `'a' >> char_('b')` are Spirit sequence parsers for the letter `'a'` followed by `'b'`. You'll get used to it, sooner or later.

Finally, take note that we test for a full match (i.e. the parser fully parsed the input) by checking if the first iterator, after parsing, is equal to the end iterator. You may strike out this part if partial matches are to be allowed.

Semantic Actions

The example in the previous section was very simplistic. It only recognized data, but did nothing with it. It answered the question: "Did the input match?". Now, we want to extract information from what was parsed. For example, we would want to store the parsed number after a successful match. To do this, you will need *semantic actions*.

Semantic actions may be attached to any point in the grammar specification. These actions are C++ functions or function objects that are called whenever a part of the parser successfully recognizes a portion of the input. Say you have a parser `P`, and a C++ function `F`. You can make the parser call `F` whenever it matches an input by attaching `F`:

```
P[F]
```

The expression above links `F` to the parser, `P`.

The function/function object signature depends on the type of the parser to which it is attached. The parser `double_` passes the parsed number. Thus, if we were to attach a function `F` to `double_`, we need `F` to be declared as:

```
void F(double n);
```

There are actually 2 more arguments being passed (the parser context and a reference to a boolean 'hit' parameter). We don't need these, for now, but we'll see more on these other arguments later. Spirit.Qi allows us to bind a single argument function, like above. The other arguments are simply ignored.

Examples of Semantic Actions

Presented are various ways to attach semantic actions:

- Using plain function pointer
- Using simple function object
- Using Boost.Bind with a plain function
- Using Boost.Bind with a member function
- Using Boost.Lambda

Given:

```
namespace client
{
    namespace qi = boost::spirit::qi;

    // A plain function
    void print(int const& i)
    {
        std::cout << i << std::endl;
    }

    // A member function
    struct writer
    {
        void print(int const& i) const
        {
            std::cout << i << std::endl;
        }
    };

    // A function object
    struct print_action
    {
        void operator()(int const& i, qi::unused_type, qi::unused_type) const
        {
            std::cout << i << std::endl;
        }
    };
}
```

Take note that with function objects, we need to have an `operator()` with 3 arguments. Since we don't care about the other two, we can use `unused_type` for these. We'll see more of `unused_type` elsewhere. `unused_type` is a Spirit supplied support class.

All examples parse inputs of the form:

```
"{integer}"
```

An integer inside the curly braces.

The first example shows how to attach a plain function:

```
parse(first, last, '{' >> int_[&print] >> '}');
```

What's new? Well `int_` is the sibbling of `double_`. I'm sure you can guess what this parser does.

The next example shows how to attach a simple function object:

```
parse(first, last, '{' >> int_[print_action()] >> '}');
```

We can use Boost.Bind to 'bind' member functions:

```
writer w;
parse(first, last, '{' >> int_[boost::bind(&writer::print, &w, _1)] >> '}');
```

Likewise, we can also use Boost.Bind to 'bind' plain functions:

```
parse(first, last, '{' >> int_[boost::bind(&print, _1)] >> '}');
```

Yep, we can also use Boost.Lambda:

```
parse(first, last, '{' >> int_[std::cout << _1 << '\n'] >> '}');
```

There are more ways to bind semantic action functions, but the examples above are the most common. Attaching semantic actions is the first hurdle one has to tackle when getting started with parsing with Spirit. Familiarize yourself with this task and get intimate with the tools behind it such as Boost.Bind and Boost.Lambda.

The examples above can be found here: ../../example/qi/actions.cpp

Phoenix

Phoenix, a companion library bundled with Spirit, is specifically suited for binding semantic actions. It is like Boost.Lambda on steroids, with special custom features that make it easy to integrate semantic actions with Spirit. If your requirements go beyond simple to moderate parsing, it is suggested that you use this library. All the following examples in this tutorial will use Phoenix for sematic actions.

Important

There are different ways to write semantic actions for *Spirit.Qi*: using plain functions, Boost.Bind, Boost.Lambda, or Phoenix. The latter three allow you to use special placeholders to control parameter placement (`_1`, `_2`, etc.). Each of those libraries has it's own implementation of the placeholders, all in different namespaces. You have to make sure not to mix placeholders with a library they don't belong to and not to use different libraries while writing a semantic action.

Generally, for Boost.Bind, use `::_1`, `::_2`, etc. (yes, these placeholders are defined in the global namespace).

For Boost.Lambda use the placeholders defined in the namespace `boost::lambda`.

For semantic actions written using Phoenix use the placeholders defined in the namespace `boost::spirit`. Please note that all existing placeholders for your convenience are also available from the namespace `boost::spirit::qi`.

Complex - Our first complex parser

Well, not really a complex parser, but a parser that parses complex numbers. This time, we're using Phoenix to do the semantic actions.

Here's a simple parser expression for complex numbers:

```
    '(' >> double_ >> -(',' >> double_) >> ')'
|   double_
```

What's new? Well, we have:

1. Alternates: e.g. `a | b`. Try `a` first. If it succeeds, good. If not, try the next alternative, `b`.

2. Optionals: e.g. -p. Match the parser p zero or one time.

The complex parser presented above reads as:

- One or two real number in parantheses, separated by comma (the second number is optional)
- **OR** a single real number.

This parser can parse complex numbers of the form:

```
(123.45, 987.65)
(123.45)
123.45
```

Here goes, this time with actions:

```
namespace client
{
    template <typename Iterator>
    bool parse_complex(Iterator first, Iterator last, std::complex<double>& c)
    {
        using boost::spirit::qi::double_;
        using boost::spirit::qi::_1;
        using boost::spirit::qi::phrase_parse;
        using boost::spirit::ascii::space;
        using boost::phoenix::ref;

        double rN = 0.0;
        double iN = 0.0;
        bool r = phrase_parse(first, last,

            //  Begin grammar
            (
                    '(' >> double_[ref(rN) = _1]
                        >> -(',' >> double_[ref(iN) = _1]) >> ')'
                |   double_[ref(rN) = _1]
            ),
            //  End grammar

            space);

        if (!r || first != last) // fail if we did not get a full match
            return false;
        c = std::complex<double>(rN, iN);
        return r;
    }
}
```

The full cpp file for this example can be found here: ../../example/qi/complex_number.cpp

Note

Those with experience using Phoenix might be confused with the placeholders that we are using (i.e. `_1`, `_2`, etc.). Please be aware that we are not using the same placeholders supplied by Phoenix. Take note that we are pulling in the placeholders from namespace `boost::spirit::qi`. These placeholders are specifically tailored for Spirit.

The `double_` parser attaches this action:

```
ref(n) = _1
```

This assigns the parsed result (actually, the attribute of `double_`) to `n`. `ref(n)` tells Phoenix that `n` is a mutable reference. `_1` is a Phoenix placeholder for the parsed result attribute.

Sum - adding numbers

Here's a parser that sums a comma-separated list of numbers.

Ok we've glossed over some details in our previous examples. First, our includes:

```
#include <boost/spirit/include/qi.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <iostream>
#include <string>
```

Then some using directives:

```
namespace qi = boost::spirit::qi;
namespace ascii = boost::spirit::ascii;
namespace phoenix = boost::phoenix;

using qi::double_;
using qi::_1;
using ascii::space;
using phoenix::ref;
```

Namespace	Description
boost::phoenix	All of phoenix
boost::spirit	All of spirit
boost::spirit::qi	All of spirit.qi
boost::spirit::ascii	ASCII version of `char_` and all char related parsers. Other encodings are also provided (e.g. also an ISO8859.1)
boost::spirit::arg_names	Special phoenix placeholders for spirit

Note

If you feel uneasy with using whole namespaces, feel free to qualify your code, use namespace aliases, etc. For the purpose of this tutorial, we will be presenting unqualified names for both Spirit and Phoenix. No worries, we will always present the full working code, so you won't get lost. In fact, all examples in this tutorial have a corresponding cpp file that QuickBook (the documentation tool we are using) imports in here as code snippets.

Now the actual parser:

```
template <typename Iterator>
bool adder(Iterator first, Iterator last, double& n)
{
    bool r = qi::phrase_parse(first, last,

        //  Begin grammar
        (
            double_[ref(n) = _1] >> *(',' >> double_[ref(n) += _1])
        )
        ,
        //  End grammar

        space);

    if (first != last) // fail if we did not get a full match
        return false;
    return r;
}
```

The full cpp file for this example can be found here: ../../example/qi/sum.cpp

This is almost like our original numbers list example. We're incrementally building on top of our examples. This time though, like in the complex number example, we'll be adding the smarts. There's an accumulator (`double& n`) that adds the numbers parsed. On a successful parse, this number is the sum of all the parsed numbers.

The first `double_` parser attaches this action:

```
ref(n) = _1
```

This assigns the parsed result (actually, the attribute of `double_`) to `n`. `ref(n)` tells Phoenix that `n` is a mutable reference. `_1` is a Phoenix placeholder for the parsed result attribute.

The second `double_` parser attaches this action:

```
ref(n) += _1
```

So, subsequent numbers add into `n`.

That wasn't too bad, was it :-) ?

Number List - stuffing numbers into a std::vector

This sample demontrates a parser for a comma separated list of numbers. The numbers are inserted in a vector using phoenix.

```
template <typename Iterator>
bool parse_numbers(Iterator first, Iterator last, std::vector<double>& v)
{
    using qi::double_;
    using qi::phrase_parse;
    using qi::_1;
    using ascii::space;
    using phoenix::push_back;
    using phoenix::ref;

    bool r = phrase_parse(first, last,

        //  Begin grammar
        (
            double_[push_back(ref(v), _1)]
                >> *(',' >> double_[push_back(ref(v), _1)])
        )
        ,
        //  End grammar

        space);

    if (first != last) // fail if we did not get a full match
        return false;
    return r;
}
```

The full cpp file for this example can be found here: ../../example/qi/num_list2.cpp

This, again, is the same parser as before. This time, instead of summing up the numbers, we stuff them in a `std::vector`. `push_back` is supplied by Phoenix. The expression:

```
push_back(ref(v), _1)
```

appends the parsed number. Like before, `_1` is a Phoenix placeholder for the parsed result attribute. Also, like before, `ref(v)` tells Phoenix that `v`, the `std::vector`, is a mutable reference.

Number List Redux - list syntax

So far, we've been using the syntax:

```
double_ >> *(',' >> double_)
```

to parse a comma-delimited list of numbers. Such lists are common in parsing and Spirit provides a simpler shortcut for them. The expression above can be simplified to:

```
double_ % ','
```

read as: a list of doubles separated by `','`.

This sample, again a variation of our previous example, demonstrates just that:

```
template <typename Iterator>
bool parse_numbers(Iterator first, Iterator last, std::vector<double>& v)
{
    using qi::double_;
    using qi::phrase_parse;
    using qi::_1;
    using ascii::space;
    using phoenix::push_back;
    using phoenix::ref;

    bool r = phrase_parse(first, last,

        //  Begin grammar
        (
            double_[push_back(ref(v), _1)] % ','
        )
        ,
        //  End grammar

        space);

    if (first != last) // fail if we did not get a full match
        return false;
    return r;
}
```

The full cpp file for this example can be found here: ../../example/qi/num_list3.cpp

Number List Attribute - one more, with style

You've seen that the `double_` parser has a `double` attribute. All parsers have an attribute, even complex parsers, those that are composed from primitives using operators, like the list parser, also have an attribute. It so happens that the the attribute of a list parser:

```
p % d
```

is a `std::vector` of the attribute of `p`. So, for our parser:

```
double_ % ','
```

we'll have an attribute of:

```
std::vector<double>
```

So, what does this give us? Well, we can simply pass in a `std::vector<double>` to our number list parser and it will happily churn out our result in our vector. For that to happen, we'll use a variation of the `phrase_parse` with an additional argument: the parser's attribute. With the following arguments passed to `phrase_parse`

1. An iterator pointing to the start of the input
2. An iterator pointing to one past the end of the input
3. The parser object
4. Another parser called the skip parser
5. The parser's attribute

our parser now is further simplified to:

```
template <typename Iterator>
bool parse_numbers(Iterator first, Iterator last, std::vector<double>& v)
{
    using qi::double_;
    using qi::phrase_parse;
    using qi::_1;
    using ascii::space;

    bool r = phrase_parse(first, last,

        //  Begin grammar
        (
            double_ % ','
        )
        ,
        //  End grammar

        space, v);

    if (first != last) // fail if we did not get a full match
        return false;
    return r;
}
```

The full cpp file for this example can be found here: ../../example/qi/num_list4.cpp

Hey, no more actions!!! Now we're entering the realm of attribute grammars. Cool eh?

Roman Numerals

This example demonstrates:

- symbol table
- rule
- grammar

Symbol Table

The symbol table holds a dictionary of symbols where each symbol is a sequence of characters (a `char`, `wchar_t`, `int`, enumeration etc.) . The template class, parameterized by the character type, can work efficiently with 8, 16, 32 and even 64 bit characters. Mutable data of type T is associated with each symbol.

Traditionally, symbol table management is maintained seperately outside the BNF grammar through semantic actions. Contrary to standard practice, the Spirit symbol table class `symbols` is a parser, an object of which may be used anywhere in the EBNF grammar specification. It is an example of a dynamic parser. A dynamic parser is characterized by its ability to modify its behavior at run time. Initially, an empty symbols object matches nothing. At any time, symbols may be added or removed, thus, dynamically altering its behavior.

Each entry in a symbol table has an associated mutable data slot. In this regard, one can view the symbol table as an associative container (or map) of key-value pairs where the keys are strings.

The symbols class expects two template parameters. The first parameter specifies the character type of the symbols. The second specifies the data type associated with each symbol: its attribute.

Here's a parser for roman hundreds (100..900) using the symbol table. Keep in mind that the data associated with each slot is the parser's attribute (which is passed to attached semantic actions).

```
struct hundreds_ : qi::symbols<char, unsigned>
{
    hundreds_()
    {
        add
            ("C"    , 100)
            ("CC"   , 200)
            ("CCC"  , 300)
            ("CD"   , 400)
            ("D"    , 500)
            ("DC"   , 600)
            ("DCC"  , 700)
            ("DCCC" , 800)
            ("CM"   , 900)
        ;
    }

} hundreds;
```

Here's a parser for roman tens (10..90):

```
struct tens_ : qi::symbols<char, unsigned>
{
    tens_()
    {
        add
            ("X"    , 10)
            ("XX"   , 20)
            ("XXX"  , 30)
            ("XL"   , 40)
            ("L"    , 50)
            ("LX"   , 60)
            ("LXX"  , 70)
            ("LXXX" , 80)
            ("XC"   , 90)
        ;
    }

} tens;
```

and, finally, for ones (1..9):

```
struct ones_ : qi::symbols<char, unsigned>
{
    ones_()
    {
        add
            ("I"    , 1)
            ("II"   , 2)
            ("III"  , 3)
            ("IV"   , 4)
            ("V"    , 5)
            ("VI"   , 6)
            ("VII"  , 7)
            ("VIII" , 8)
            ("IX"   , 9)
        ;
    }

} ones;
```

Now we can use `hundreds`, `tens` and `ones` anywhere in our parser expressions. They are all parsers.

Rules

Up until now, we've been inlining our parser expressions, passing them directly to the `phrase_parse` function. The expression evaluates into a temporary, unnamed parser which is passed into the `phrase_parse` function, used, and then destroyed. This is fine for small parsers. When the expressions get complicated, you'd want to break the expressions into smaller easier to understand pieces, name them, and refer to them from other parser expressions by name.

A parser expression can be assigned to, what is called, a "rule". There are various ways to declare rules. The simplest form is:

```
rule<Iterator> r;
```

At the very least, the rule needs to know the iterator type it will be working on. This rule cannot be used with `phrase_parse`. It can only be used with the `parse` function -- a version that does not do white space skipping (does not have the skipper argument). If you want to have it skip white spaces, you need to pass in the type skip parser, as in the next form:

```
rule<Iterator, Skipper> r;
```

Example:

```
rule<std::string::iterator, space_type> r;
```

This type of rule can be used for both `phrase_parse` and `parse`.

For our next example, there's one more rule form you should know about:

```
rule<Iterator, Signature> r;
```

or

```
rule<Iterator, Signature, Skipper> r;
```

Tip

All rule template arguments after Iterator can be supplied in any order.

The Signature specifies the attributes of the rule. You've seen that our parsers can have an attribute. Recall that the `double_` parser has an attribute of `double`. To be precise, these are *synthesized* attributes. The parser "synthesizes" the attribute value. Think of them as function return values.

There's another type of attribute called "inherited" attribute. We won't need them for now, but it's good that you be aware of such attributes. You can think of them as function arguments. And, rightly so, the rule signature is a function signature of the form:

```
result(argN, argN,..., argN)
```

After having declared a rule, you can now assign any parser expression to it. Example:

```
r = double_ >> *(',' >> double_);
```

Grammars

A grammar encapsulates one or more rules. It has the same template parameters as the rule. You declare a grammar by:

1. deriving a struct (or class) from the `grammar` class template
2. declare one or more rules as member variables
3. initialize the base grammar class by giving it the start rule (its the first rule that gets called when the grammar starts parsing)
4. initialize your rules in your constructor

The roman numeral grammar is a very nice and simple example of a grammar:

```
template <typename Iterator>
struct roman : qi::grammar<Iterator, unsigned()>
{
    roman() : roman::base_type(start)
    {
        using qi::eps;
        using qi::lit;
        using qi::_val;
        using qi::_1;
        using ascii::char_;

        start = eps             [_val = 0] >>
            (
                +lit('M')       [_val += 1000]
                ||  hundreds    [_val += _1]
                ||  tens        [_val += _1]
                ||  ones        [_val += _1]
            )
        ;
    }

    qi::rule<Iterator, unsigned()> start;
};
```

Things to take notice of:

- The grammar and start rule signature is `unsigned()`. It has a synthesized attribute (return value) of type `unsigned` with no inherited attributes (arguments).
- We did not specify a skip-parser. We don't want to skip in between the numerals.
- `roman::base_type` is a typedef for `grammar<Iterator, unsigned()>`. If `roman` was not a template, you can simply write: base_type(start)
- But it's best to make your grammar templates, so that they can be reused for different iterator types.
- `_val` is another Phoenix placeholder representing the rule's synthesized attribute.
- `eps` is a special spirit parser that consumes no input but is always successful. We use it to initialize `_val`, the rule's synthesized attribute, to zero before anything else. The actual parser starts at `+char_('M')`, parsing roman thousands. Using `eps` this way is good for doing pre and post initializations.
- The expression `a || b` reads: match a or b and in sequence. That is, if both `a` and `b` match, it must be in sequence; this is equivalent to `a >> -b | b`, but more efficient.

Let's Parse!

```
bool r = parse(iter, end, roman_parser, result);

if (r && iter == end)
{
    std::cout << "-------------------------\n";
    std::cout << "Parsing succeeded\n";
    std::cout << "result = " << result << std::endl;
    std::cout << "-------------------------\n";
}
else
{
    std::string rest(iter, end);
    std::cout << "-------------------------\n";
    std::cout << "Parsing failed\n";
    std::cout << "stopped at: \": " << rest << "\"\n";
    std::cout << "-------------------------\n";
}
```

`roman_parser` is an object of type `roman`, our roman numeral parser. This time around, we are using the no-skipping version of the parse functions. We do not want to skip any spaces! We are also passing in an attribute, `unsigned result`, which will receive the parsed value.

The full cpp file for this example can be found here: ../../example/qi/roman.cpp

Employee - Parsing into structs

It's a common question in the Spirit General List: How do I parse and place the results into a C++ struct? Of course, at this point, you already know various ways to do it, using semantic actions. There are many ways to skin a cat. Spirit2, being fully attributed, makes it even easier. The next example demonstrates some features of Spirit2 that make this easy. In the process, you'll learn about:

- More about attributes
- Auto rules
- Some more built-in parsers
- Directives

First, let's create a struct representing an employee:

```
struct employee
{
    int age;
    std::string surname;
    std::string forename;
    double salary;
};
```

Then, we need to tell Boost.Fusion about our employee struct to make it a first-class fusion citizen that the grammar can utilize. If you don't know fusion yet, it is a Boost library for working with heterogenous collections of data, commonly referred to as tuples. Spirit uses fusion extensively as part of its infrastructure.

In fusion's view, a struct is just a form of a tuple. You can adapt any struct to be a fully conforming fusion tuple:

```
BOOST_FUSION_ADAPT_STRUCT(
    client::employee,
    (int, age)
    (std::string, surname)
    (std::string, forename)
    (double, salary)
)
```

Now we'll write a parser for our employee. Inputs will be of the form:

```
employee{ age, "surname", "forename", salary }
```

Here goes:

```
template <typename Iterator>
struct employee_parser : qi::grammar<Iterator, employee(), ascii::space_type>
{
    employee_parser() : employee_parser::base_type(start)
    {
        using qi::int_;
        using qi::lit;
        using qi::double_;
        using qi::lexeme;
        using ascii::char_;

        quoted_string %= lexeme['"' >> +(char_ - '"') >> '"'];

        start %=
            lit("employee")
            >> '{'
            >>  int_ >> ','
            >>  quoted_string >> ','
            >>  quoted_string >> ','
            >>  double_
            >>  '}'
            ;
    }

    qi::rule<Iterator, std::string(), ascii::space_type> quoted_string;
    qi::rule<Iterator, employee(), ascii::space_type> start;
};
```

The full cpp file for this example can be found here: ../../example/qi/employee.cpp

Let's walk through this one step at a time (not necessarily from top to bottom).

```
template <typename Iterator>
struct employee_parser : grammar<Iterator, employee(), space_type>
```

`employee_parser` is a grammar. Like before, we make it a template so that we can reuse it for different iterator types. The grammar's signature is:

```
employee()
```

meaning, the parser generates employee structs. `employee_parser` skips white spaces using `space_type` as its skip parser.

```
employee_parser() : employee_parser::base_type(start)
```

Initializes the base class.

```
rule<Iterator, std::string(), space_type> quoted_string;
rule<Iterator, employee(), space_type> start;
```

Declares two rules: `quoted_string` and `start`. `start` has the same template parameters as the grammar itself. `quoted_string` has a `std::string` attribute.

Lexeme

```
lexeme['"' >> +(char_ - '"') >> '"'];
```

`lexeme` inhibits space skipping from the open brace to the closing brace. The expression parses quoted strings.

```
+(char_ - '"')
```

parses one or more chars, except the double quote. It stops when it sees a double quote.

Difference

The expression:

```
a - b
```

parses `a` but not `b`. Its attribute is just `A`, the attribute of `a`. `b`'s attribute is ignored. Hence, the attribute of:

```
char_ - '"'
```

is just `char`.

Plus

```
+a
```

is similar to kleene star. Rather than match everything, `+a` matches one or more. Like it's related function, the kleene star, its attribute is a `std::vector<A>` where `A` is the attribute of `a`. So, putting all these together, the attribute of

```
+(char_ - '"')
```

is then:

```
std::vector<char>
```

Sequence Attribute

Now what's the attribute of

```
'"' >> +(char_ - '"') >> '"'
```

?

Well, typically, the attribute of:

```
a >> b >> c
```

is:

```
fusion::vector<A, B, C>
```

where `A` is the attribute of `a`, `B` is the attribute of `b` and `C` is the attribute of `c`. What is `fusion::vector`? - a tuple.

Note

If you don't know what I am talking about, see: Fusion Vector. It might be a good idea to have a look into Boost.Fusion at this point. You'll definitely see more of it in the coming pages.

Attribute Collapsing

Some parsers, especially those very little literal parsers you see, like `'"'`, do not have attributes.

Nodes without attributes are disregarded. In a sequence, like above, all nodes with no attributes are filtered out of the `fusion::vector`. So, since `'"'` has no attribute, and `+(char_ - '"')` has a `std::vector<char>` attribute, the whole expression's attribute should have been:

```
fusion::vector<std::vector<char> >
```

But wait, there's one more collapsing rule: If after the attribute is a single element `fusion::vector`, The element is stripped naked from its container. So, to make a long story short, the attribute of the expression:

```
'"' >> +(char_ - '"') >> '"'
```

is:

```
std::vector<char>
```

Auto Rules

It is typical to see rules like:

```
r = p[_val = _1];
```

If you have a rule definition like above where the attribute of the RHS (right hand side) of the rule is compatibe with the attribute of the LHS (left hand side), then you can rewrite it as:

```
r %= p;
```

The attribute of `p` automatically uses the attribute of `r`.

So, going back to our `quoted_string` rule:

```
quoted_string %= lexeme['"' >> +(char_ - '"') >> '"'];
```

is a simplified version of:

```
quoted_string = lexeme['"' >> +(char_ - '"') >> '"'][val_ = _1];
```

The attribute of the `quoted_string` rule: `std::string` **is compatible** with the attribute of the RHS: `std::vector<char>`. The RHS extracts the parsed attribute directly into the rule's attribute, in-situ.

Note

`r %= p` and `r = p` are equivalent if there are no semantic actions associated with `p`.

Finally

We're down to one rule, the start rule:

```
start %=
    lit("employee")
    >> '{'
    >>  int_ >> ','
    >>  quoted_string >> ','
    >>  quoted_string >> ','
    >>  double_
    >>  '}'
    ;
```

Applying our collapsing rules above, the RHS has an attribute of:

```
fusion::vector<int, std::string, std::string, double>
```

These nodes do not have an attribute:

- `lit("employee")`
- `'{'`
- `','`
- `'}'`

Note

In case you are wondering, `lit("employee")` is the same as "employee". We had to wrap it inside `lit` because immediately after it is `>> '{'`. You can't right-shift a `char[]` and a `char` - you know, C++ syntax rules.

Recall that the attribute of `start` is the `employee` struct:

```
struct employee
{
    int age;
    std::string surname;
    std::string forename;
    double salary;
};
```

Now everything is clear, right? The `struct employee` **IS** compatible with `fusion::vector<int, std::string, std::string, double>`. So, the RHS of `start` uses start's attribute (a `struct employee`) in-situ when it does its work.

Mini XML - ASTs!

Stop and think about it... We've come very close to generating an AST (abstract syntax tree) in our last example. We parsed a single structure and generated an in-memory representation of it in the form of a struct: the `struct employee`. If we changed the implementation to parse one or more employees, the result would be a `std::vector<employee>`. We can go on and add more hierarchy: teams, departments, corporations. Then we'll have an AST representation of it all.

In this example (actually two examples), we'll now explore how to create ASTs. We will parse a minimalistic XML like language and compile the results into our data structures in the form of a tree.

Along the way, we'll see new features:

- Inherited attributes
- Variant attributes
- Local Variables
- Not Predicate
- Lazy Lit

The full cpp files for these examples can be found here: ../../example/qi/mini_xml1.cpp and here: ../../example/qi/mini_xml2.cpp

There are a couple of sample toy-xml files in: ../../example/qi/mini_xml_samples for testing purposes. "4.toyxml" has an error in it.

First Cut

Without further delay, here's the first version of the XML grammar:

```
template <typename Iterator>
struct mini_xml_grammar : qi::grammar<Iterator, mini_xml(), ascii::space_type>
{
    mini_xml_grammar() : mini_xml_grammar::base_type(xml)
    {
        using qi::lit;
        using qi::lexeme;
        using ascii::char_;
        using ascii::string;
        using namespace qi::labels;

        using phoenix::at_c;
        using phoenix::push_back;

        text = lexeme[+(char_ - '<')        [_val += _1]];
        node = (xml | text)                 [_val = _1];

        start_tag =
                '<'
            >>  !lit('/')
            >>  lexeme[+(char_ - '>')       [_val += _1]]
            >>  '>'
        ;

        end_tag =
                "</"
            >>  string(_r1)
            >>  '>'
        ;

        xml =
                start_tag                   [at_c<0>(_val) = _1]
            >>  *node                       [push_back(at_c<1>(_val), _1)]
            >>  end_tag(at_c<0>(_val))
        ;
    }

    qi::rule<Iterator, mini_xml(), ascii::space_type> xml;
    qi::rule<Iterator, mini_xml_node(), ascii::space_type> node;
    qi::rule<Iterator, std::string(), ascii::space_type> text;
    qi::rule<Iterator, std::string(), ascii::space_type> start_tag;
    qi::rule<Iterator, void(std::string), ascii::space_type> end_tag;
};
```

Going bottom up, let's examine the `text` rule:

```
rule<Iterator, std::string(), space_type> text;
```

and its definition:

```
text = lexeme[+(char_ - '<')        [_val += _1]];
```

The semantic action collects the chars and appends them (via +=) to the `std::string` attribute of the rule (represented by the placeholder `_val`).

Alternates

```
rule<Iterator, mini_xml_node(), space_type> node;
```

and its definition:

```
node = (xml | text)                 [_val = _1];
```

We'll see what a `mini_xml_node` structure is later. Looking at the rule definition, we see some alternation going on here. An xml `node` is either an `xml` OR `text`. Hmmm... hold on to that thought...

```
rule<Iterator, std::string(), space_type> start_tag;
```

Again, with an attribute of `std::string`. Then, it's definition:

```
start_tag =
        '<'
    >>  !char_('/')
    >>  lexeme[+(char_ - '>')       [_val += _1]]
    >>  '>'
;
```

Not Predicate

`start_tag` is similar to the `text` rule apart from the added `'<'` and `'>'`. But wait, to make sure that the `start_tag` does not parse `end_tag`s too, we add: `!char_('/')`. This is a "Not Predicate":

```
!p
```

It will try the parser, `p`. If it is successful, fail, otherwise, pass. In other words, it negates the result of `p`. Like the `eps`, it does not consume any input though. It will always rewind the iterator position to where it was upon entry. So, the expression:

```
!char_('/')
```

basically says: we should not have a `'/'` at this point.

Inherited Attribute

The `end_tag`:

```
rule<Iterator, void(std::string), space_type> end_tag;
```

Ohh! Now we see an inherited attribute there: `std::string`. The `end_tag` does not have a synthesized attribute. Let's see its definition:

```
end_tag =
        "</"
    >>  lit(_r1)
    >>  '>'
;
```

`_r1` is yet another Phoenix placeholder for the first inherited attribute (we have only one, use `_r2`, `_r3`, etc. if you have more).

A Lazy Lit

Check out how we used `lit` here, this time, not with a literal string, but with the value of the first inherited attribute, which is specified as `std::string` in our rule declaration.

Finally, our `xml` rule:

```
rule<Iterator, mini_xml(), space_type> xml;
```

`mini_xml` is our attribute here. We'll see later what it is. Let's see its definition:

```
xml =
        start_tag                   [at_c<0>(_val) = _1]
    >>  *node                       [push_back(at_c<1>(_val), _1)]
    >>  end_tag(at_c<0>(_val))
;
```

Those who know Boost.Fusion now will notice `at_c<0>` and `at_c<1>`. This gives us a hint that `mini_xml` is a sort of a tuple - a fusion sequence. `at_c<N>` here is a lazy version of the tuple accessors, provided by Phoenix.

How it all works

So, what's happening?

1. Upon parsing `start_tag`, the parsed start-tag string is placed in `at_c<0>(_val)`.
2. Then we parse zero or more `nodes`. At each step, we `push_back` the result into `at_c<1>(_val)`.
3. Finally, we parse the `end_tag` giving it an inherited attribute: `at_c<0>(_val)`. This is the string we obtained from the `start_tag`. Investigate `end_tag` above. It will fail to parse if it gets something different from what we got from the `start_tag`. This ensures that our tags are balanced.

To give the last item some more light, what happens is this:

```
end_tag(at_c<0>(_val))
```

calls:

```
end_tag =
        "</"
    >>  lit(_r1)
    >>  '>'
;
```

passing in `at_c<0>(_val)`, the string from start tag. This is referred to in the `end_tag` body as `_r1`.

The Structures

Let's see our structures. It will definitely be hierarchical: xml is hierarchical. It will also be recursive: xml is recursive.

```
struct mini_xml;

typedef
    boost::variant<
        boost::recursive_wrapper<mini_xml>
      , std::string
    >
mini_xml_node;

struct mini_xml
{
    std::string name;                           // tag name
    std::vector<mini_xml_node> children;        // children
};
```

Of Alternates and Variants

So that's what a `mini_xml_node` looks like. We had a hint that it is either a `string` or a `mini_xml`. For this, we use Boost.Variant. `boost::recursive_wrapper` wraps `mini_xml`, making it a recursive data structure.

Yep, you got that right: the attribute of an alternate:

```
a | b
```

is a

```
boost::variant<A, B>
```

where `A` is the attribute of `a` and `B` is the attribute of `b`.

Adapting structs again

`mini_xml` is no brainier. It is a plain ol' struct. But as we've seen in our employee example, we can adapt that to be a Boost.Fusion sequence:

```
BOOST_FUSION_ADAPT_STRUCT(
    client::mini_xml,
    (std::string, name)
    (std::vector<client::mini_xml_node>, children)
)
```

One More Take

Here's another version. The AST structure remains the same, but this time, you'll see that we make use of auto-rules making the grammar semantic-action-less. Here it is:

```
template <typename Iterator>
struct mini_xml_grammar
  : qi::grammar<Iterator, mini_xml(), qi::locals<std::string>, ascii::space_type>
{
    mini_xml_grammar()
      : mini_xml_grammar::base_type(xml)
    {
        using qi::lit;
        using qi::lexeme;
        using ascii::char_;
        using ascii::string;
        using namespace qi::labels;

        text %= lexeme[+(char_ - '<')];
        node %= xml | text;

        start_tag %=
                '<'
            >>  !lit('/')
            >>  lexeme[+(char_ - '>')]
            >>  '>'
        ;

        end_tag =
                "</"
            >>  string(_r1)
            >>  '>'
        ;

        xml %=
                start_tag[_a = _1]
            >>  *node
            >>  end_tag(_a)
        ;
    }

    qi::rule<Iterator, mini_xml(), qi::locals<std::string>, ascii::space_type> xml;
    qi::rule<Iterator, mini_xml_node(), ascii::space_type> node;
    qi::rule<Iterator, std::string(), ascii::space_type> text;
    qi::rule<Iterator, std::string(), ascii::space_type> start_tag;
    qi::rule<Iterator, void(std::string), ascii::space_type> end_tag;
};
```

This one shouldn't be any more difficult to understand after going through the first xml parser example. The rules are almost the same, except that, we got rid of semantic actions and used auto-rules (see the employee example if you missed that). There is some new stuff though. It's all in the `xml` rule:

Local Variables

```
rule<Iterator, mini_xml(), locals<std::string>, space_type> xml;
```

Wow, we have four template parameters now. What's that `locals` guy doing there? Well, it declares that the rule `xml` will have one local variable: a `string`. Let's see how this is used in action:

```
xml %=
        start_tag[_a = _1]
    >>  *node
    >>  end_tag(_a)
;
```

1. Upon parsing `start_tag`, the parsed start-tag string is placed in the local variable specified by (yet another) Phoenix placeholder: _a. We have only one local variable. If we had more, these are designated by _b.._z.

2. Then we parse zero or more `node`s.

3. Finally, we parse the `end_tag` giving it an inherited attribute: _a, our local variable.

There are no actions involved in stuffing data into our `xml` attribute. It's all taken care of thanks to the auto-rule.

Mini XML - Error Handling

A parser will not be complete without error handling. Spirit2 provides some facilities to make it easy to adapt a grammar for error handling. We'll wrap up the Qi tutorial with another version of the mini xml parser, this time, with error handling.

The full cpp file for this example can be found here: ../../example/qi/mini_xml3.cpp

Here's the grammar:

```
template <typename Iterator>
struct mini_xml_grammar
  : qi::grammar<Iterator, mini_xml(), qi::locals<std::string>, ascii::space_type>
{
    mini_xml_grammar()
      : mini_xml_grammar::base_type(xml, "xml")
    {
        using qi::lit;
        using qi::lexeme;
        using qi::on_error;
        using qi::fail;
        using ascii::char_;
        using ascii::string;
        using namespace qi::labels;

        using phoenix::construct;
        using phoenix::val;

        text %= lexeme[+(char_ - '<')];
        node %= xml | text;

        start_tag %=
                '<'
            >>  !lit('/')
            >   lexeme[+(char_ - '>')]
            >   '>'
        ;

        end_tag =
                "</"
            >   string(_r1)
            >   '>'
        ;

        xml %=
                start_tag[_a = _1]
            >   *node
            >   end_tag(_a)
        ;

        xml.name("xml");
        node.name("node");
        text.name("text");
        start_tag.name("start_tag");
        end_tag.name("end_tag");

        on_error<fail>
        (
            xml
          , std::cout
                << val("Error! Expecting ")
                << _4                               // what failed?
                << val(" here: \"")
                << construct<std::string>(_3, _2)   // iterators to error-pos, end
                << val("\"")
                << std::endl
        );
    }
```

```
    qi::rule<Iterator, mini_xml(), qi::locals<std::string>, ascii::space_type> xml;
    qi::rule<Iterator, mini_xml_node(), ascii::space_type> node;
    qi::rule<Iterator, std::string(), ascii::space_type> text;
    qi::rule<Iterator, std::string(), ascii::space_type> start_tag;
    qi::rule<Iterator, void(std::string), ascii::space_type> end_tag;
};
```

What's new?

Readable Names

First, when we call the base class, we give the grammar a name:

```
: mini_xml_grammar::base_type(xml, "xml")
```

Then, we name all our rules:

```
xml.name("xml");
node.name("node");
text.name("text");
start_tag.name("start_tag");
end_tag.name("end_tag");
```

On Error

`on_error` declares our error handler:

```
on_error<Action>(rule, handler)
```

This will specify what we will do when we get an error. We will print out an error message using phoenix:

```
on_error<fail>
(
    xml
  , std::cout
        << val("Error! Expecting ")
        << _4                               // what failed?
        << val(" here: \"")
        << construct<std::string>(_3, _2)   // iterators to error-pos, end
        << val("\"")
        << std::endl
);
```

we choose to `fail` in our example for the `Action`: Quit and fail. Return a no_match (false). It can be one of:

`Action`	**Description**
fail	Quit and fail. Return a no_match.
retry	Attempt error recovery, possibly moving the iterator position.
accept	Force success, moving the iterator position appropriately.
rethrow	Rethrows the error.

`rule` is the rule we attach the handler to. In our case, we are attaching to the `xml` rule.

`handler` is the actual error handling function. It expects 4 arguments:

Arg	Description
first	The position of the iterator when the rule with the handler was entered.
last	The end of input.
error-pos	The actual position of the iterator where the error occurred.
what	What failed: a string decribing the failure.

Expectation Points

You might not have noticed it, but some of our expressions changed from using the >> to >. Look, for example:

```
end_tag =
        "</"
    >   lit(_r1)
    >   '>'
;
```

What is it? It's the *expectation* operator. You will have some "deterministic points" in the grammar. Those are the places where backtracking **cannot** occur. For our example above, when you get a `"</"`, you definitely must see a valid end-tag label next. It should be the one you got from the start-tag. After that, you definitely must have a `'>'` next. Otherwise, there is no point in proceeding forward and trying other branches, regardless where they are. The input is definitely erroneous. When this happens, an expectation_failure exception is thrown. Somewhere outward, the error handler will catch the exception.

Try building the parser: ../../example/qi/mini_xml3.cpp. You can find some examples in: ../../example/qi/mini_xml_samples for testing purposes. "4.toyxml" has an error in it:

```
<foo><bar></foo></bar>
```

Running the example with this gives you:

```
Error! Expecting "bar" here: "foo></bar>"
Error! Expecting end_tag here: "<bar></foo></bar>"
-------------------------
Parsing failed
-------------------------
```

Quick Reference

This quick reference section is provided for convenience. You can use this section as a sort of a "cheat-sheet" on the most commonly used Qi components. It is not intended to be complete, but should give you an easy way to recall a particular component without having to dig up on pages and pages of reference doumentation.

Common Notation

Notation

`P`	Parser type
`p, a, b, c`	Parser objects

`A, B, C`	Attribute types of parsers `a`, `b` and `c`
`I`	The iterator type used for parsing
`Unused`	An `unused_type`
`Context`	The enclosing rule's `Context` type
`attrib`	An attribute value
`Attrib`	An attribute type
`b`	A boolean expression
`fp`	A (lazy parser) function with signature `P(Unused, Context)`
`fa`	A (semantic action) function with signature `void(Attrib, Context, bool&)`. The third parameter is a boolean flag that can be set to false to force the parse to fail. Both `Context` and the boolean flag are optional.
`first`	An iterator pointing to the start of input
`last`	An iterator pointing to the end of input
`Ch`	Character-class specific character type (See Character Class Types)
`ch`	Character-class specific character (See Character Class Types)
`ch2`	Character-class specific character (See Character Class Types)
`charset`	Character-set specifier string (example: "a-z0-9")
`str`	Character-class specific string (See Character Class Types)
`Str`	Attribute of `str`: `std::basic_string<T>` where `T` is the underlying character type of `str`
`tuple<>`	Used as a placeholder for a fusion sequence
`vector<>`	Used as a placeholder for an STL container
`variant<>`	Used as a placeholder for a boost::variant
`optional<>`	Used as a placeholder for a boost::optional

Qi Parsers

Character Parsers

Expression	Attribute	Description
`ch`	`Unused`	Matches `ch`
`lit(ch)`	`Unused`	Matches `ch`
`char_`	`Ch`	Matches any character
`char_(ch)`	`Ch`	Matches `ch`
`char_("c")`	`Ch`	Matches a single char string literal, `c`
`char_(ch, ch2)`	`Ch`	Matches a range of chars from `ch` to `ch2` (inclusive)
`char_(charset)`	`Ch`	Matches a character set `charset`
`alnum`	`Ch`	Matches a character based on the equivalent of `std::isalnum` in the current character set
`alpha`	`Ch`	Matches a character based on the equivalent of `std::isalpha` in the current character set
`blank`	`Ch`	Matches a character based on the equivalent of `std::isblank` in the current character set
`cntrl`	`Ch`	Matches a character based on the equivalent of `std::iscntrl` in the current character set
`digit`	`Ch`	Matches a character based on the equivalent of `std::isdigit` in the current character set
`graph`	`Ch`	Matches a character based on the equivalent of `std::isgraph` in the current character set
`print`	`Ch`	Matches a character based on the equivalent of `std::isprint` in the current character set
`punct`	`Ch`	Matches a character based on the equivalent of `std::ispunct` in the current character set
`space`	`Ch`	Matches a character based on the equivalent of `std::isspace` in the current character set
`xdigit`	`Ch`	Matches a character based on the equivalent of `std::isxdigit` in the current character set

Expression	Attribute	Description
`lower`	`Ch`	Matches a character based on the equivalent of `std::islower` in the current character set
`upper`	`Ch`	Matches a character based on the equivalent of `std::isupper` in the current character set

Numeric Parsers

Expression	Attribute	Description
`float_`	`float`	Parse a floating point number into a `float`
`double_`	`double`	Parse a floating point number into a `double`
`long_double`	`long double`	Parse a floating point number into a `long double`
`bin`	`unsigned`	Parse a binary integer into an `unsigned`
`oct`	`unsigned`	Parse an octal integer into an `unsigned`
`hex`	`unsigned`	Parse a hexadecimal integer into an `unsigned`
`ushort_`	`unsigned short`	Parse an unsigned short integer
`ulong_`	`unsigned long`	Parse an unsigned long integer
`uint_`	`unsigned int`	Parse an unsigned int
`ulong_long`	`unsigned long long`	Parse an unsigned long long
`short_`	`short`	Parse a short integer
`long_`	`long`	Parse a long integer
`int_`	`int`	Parse an int
`long_long`	`long long`	Parse a long long

String Parsers

Expression	Attribute	Description
`str`	`Unused`	Matches `str`
`lit(str)`	`Unused`	Matches `str`
`string(str)`	`Str`	Matches `str`
`symbols<Ch, T>`	N/A	Declare a symbol table, `sym`. `Ch` is the underlying char type of the symbol table keys. `T` is the data type associated with each key.
`sym.add (str1, val1) (str2, val2) /*...more...*/ ;`	N/A	Add symbols into a symbol table, `sym`. val1 and val2 are optional data of type `T`, the data type associated with each key.
`sym`	`T`	Matches entries in the symbol table, `sym`. If successful, returns the data associated with the key

Auxiliary Parsers

Expression	Attribute	Description
`eol`	`Unused`	Matches the end of line (`\r` or `\n` or `\r\n`)
`eoi`	`Unused`	Matches the end of input (first == last)
`eps`	`Unused`	Match an empty string
`eps(b)`	`Unused`	If `b` is true, match an empty string
`lazy(fp)`	Attribute of `P` where `P` is the return type of `fp`	Invoke `fp` at parse time, returning a parser `p` which is then called to parse.
`fp`	see `lazy(fp)` above	Equivalent to `lazy(fp)`
`attr(attrib)`	`Attrib`	Doesn't consume/parse any input, but exposes the argument `attrib` as its attribute.

Binary Parsers

Expression	Attribute	Description
`byte_`	8 bits native endian	Matches an 8 bit binary
`word`	16 bits native endian	Matches a 16 bit binary
`big_word`	16 bits big endian	Matches a 16 bit binary
`little_word`	16 bits little endian	Matches a 16 bit binary
`dword`	32 bits native endian	Matches a 32 bit binary
`big_dword`	32 bits big endian	Matches a 32 bit binary
`little_dword`	32 bits little endian	Matches a 32 bit binary
`qword`	64 bits native endian	Matches a 64 bit binary
`big_qword`	64 bits big endian	Matches a 64 bit binary
`little_qword`	64 bits little endian	Matches a 64 bit binary

Parser Directives

Expression	Attribute	Description
`lexeme[a]`	`A`	Disable skip parsing for `a`
`no_case[a]`	`A`	Inhibits case-sensitivity for `a`
`omit[a]`	`Unused`	Ignores the attribute type of `a`
`raw[a]`	`boost::iterator_range<I>`	Presents the transduction of `a` as an iterator range
`repeat[a]`	`vector<A>`	Repeat `a` zero or more times
`repeat(N)[a]`	`vector<A>`	Repeat `a` `N` times
`repeat(N, M)[a]`	`vector<A>`	Repeat `a` `N` to `M` times
`repeat(N, inf)[a]`	`vector<A>`	Repeat `a` `N` or more times
`skip[a]`	`A`	Re-establish the skipper that got inhibited by lexeme
`skip(p)[a]`	`A`	Use `p` as a skipper for parsing `a`

Parser Operators

Expression	Attribute	Description
`!a`	`Unused`	Not predicate. If the predicate a matches, fail. Otherwise, return a zero length match.
`&a`	`Unused`	And predicate. If the predicate a matches, return a zero length match. Otherwise, fail.
`-a`	`optional<A>`	Optional. Parse a zero or one time
`*a`	`vector<A>`	Kleene. Parse a zero or more times
`+a`	`vector<A>`	Plus. Parse a one or more times
`a | b`	`variant<A, B>`	Alternative. Parse a or b
`a >> b`	`tuple<A, B>`	Sequence. Parse a followed by b
`a > b`	`tuple<A, B>`	Expect. Parse a followed by b. b is expected to match when a matches, otherwise, an `expectation_failure` is thrown.
`a - b`	`A`	Difference. Parse a but not b
`a || b`	`tuple<A, B>`	Sequential Or. Parse a or b or a followed by b
`a % b`	`vector<A>`	List. Parse a delimited b one or more times
`a ^ b`	`tuple< optional<A>, optional<B> >`	Permutation. Parse a or b or a followed by b or b followed by a.

Parser Semantic Actions

Expression	Attribute	Description
`p[fa]`	Attribute of p	Call semantic action, `fa` if p succeeds.

Compound Attribute Rules

Notation

The notation we will use will be of the form:

```
a: A, b: B, ... --> composite-expression: composite-attribute
```

a, b, etc. are the operands. A, B, etc. are the operand's attribute types. `composite-expression` is the expression involving the operands and `composite-attribute` is the resulting attribute type of the composite expression.

For instance:

```
a: A, b: B --> (a >> b): tuple<A, B>
```

reads as: given, a and b are parsers, and A is the type of the attribute of a, and B is the type of the attribute of b, then the type of the attribute of a >> b will be tuple<A, B>.

Important

In the attribute tables, we will use vector<A> and tuple<A, B...> as placeholders only. The notation of vector<A> stands for *any STL container* holding elements of type A and the notation tuple<A, B...> stands for *any Boost.Fusion sequence* holding A, B, ... etc. elements. Finally, Unused stands for unused_type.

Compound Parser Attribute Types

Expression	Attribute

`a >> b`	`a: A, b: B --> (a >> b): tuple<A, B>`
	`a: A, b: Unused --> (a >> b): A`
	`a: Unused, b: B --> (a >> b): B`
	`a: Unused, b: Unused --> (a >> b): Unused`
	
	`a: A, b: A --> (a >> b): vector<A>`
	`a: vector<A>, b: A --> (a >> b): vector<A>`
	`a: A, b: vector<A> --> (a >> b): vector<A>`
	`a: vector<A>, b: vector<A> --> (a >> b): vec↵tor<A>`

`a > b`	`a: A, b: B --> (a > b): tuple<A, B>`
	`a: A, b: Unused --> (a > b): A`
	`a: Unused, b: B --> (a > b): B`
	`a: Unused, b: Unused --> (a > b): Unused`
	
	`a: A, b: A --> (a > b): vector<A>`
	`a: vector<A>, b: A --> (a > b): vector<A>`
	`a: A, b: vector<A> --> (a > b): vector<A>`
	`a: vector<A>, b: vector<A> --> (a > b): vec↵tor<A>`

`a | b`	`a: A, b: B --> (a | b): variant<A, B>`
	`a: A, b: Unused --> (a | b): optional<A>`
	`a: A, b: B, c: Unused --> (a | b | c): option↵al<variant<A, B> >`
	`a: Unused, b: B --> (a | b): optional<B>`
	`a: Unused, b: Unused --> (a | b): Unused`
	`a: A, b: A --> (a | b): A`

`a - b`	`a: A, b: B --> (a - b): A` `a: Unused, b: B --> (a - b): Unused`
`*a`	`a: A --> *a: vector<A>` `a: Unused --> *a: Unused`
`+a`	`a: A --> +a: vector<A>` `a: Unused --> +a: Unused`
`a % b`	`a: A, b: B --> (a % b): vector<A>` `a: Unused, b: B --> (a % b): Unused`
`repeat(...,...)[p]`	`a: A --> repeat(...,...)[a]: vector<A>` `a: Unused --> repeat(...,...)[a]: Unused`

Expression	Attribute

`a || b`	`a: A, b: B --> (a || b): tuple<optional<A>, optional<B> >`
	`a: A, b: Unused --> (a || b): optional<A>`
	`a: Unused, b: B --> (a || b): optional<B>`
	`a: Unused, b: Unused --> (a || b): Unused`

`-a`	`a: A --> -a: optional<A>` `a: Unused --> -a: Unused`
`&a`	`a: A --> &a: Unused`
`!b`	`a: A --> !a: Unused`

`a ^ b`	`a: A, b: B --> (a ^ b): tuple<optional<A>, optional<B> >`
	`a: A, b: Unused --> (a ^ b): optional<A>`
	`a: Unused, b: B --> (a ^ b): optional<B>`
	`a: Unused, b: Unused --> (a ^ b): Unused`

Nonterminals

Notation

`RT`	Synthesized attribute. The rule or grammar's return type.
`Arg1`, `Arg2`, `ArgN`	Inherited attributes. Zero or more arguments.
`L1`, `L2`, `LN`	Zero or more local variables.
`r`, `r2`	Rules
`g`	A grammar
`p`	A parser expression
`my_grammar`	A user defined grammar

Terminology

Signature	`RT(Arg1, Arg2 ... ,ArgN)`. The signature specifies the synthesized (return value) and inherited (arguments) attributes.
Locals	`locals<L1, L2 ..., LN>`. The local variables.
Skipper	The skip-parser type

Template Arguments

`Iterator`	The iterator type you will use for parsing.
`A1`, `A2`, `A3`	Can be one of 1) Signature 2) Locals 3) Skipper.

Expression	Description
`rule<Iterator, A1, A2, A3> r(name);`	Rule declaration. `Iterator` is required. `A1, A2, A3` are optional and can be specified in any order. `name` is an optional string that gives the rule its name, useful for debugging and error handling.
`rule<Iterator, A1, A2, A3> r(r2);`	Copy construct rule `r` from rule `r2`.
`r = r2;`	Assign rule `r2` to `r`.
`r.alias()`	return an alias of `r`. The alias is a parser that holds a reference to `r`. Reference semantics.
`r.copy()`	Get a copy of `r`.
`r.name(name)`	Naming a rule
`r.name()`	Getting the name of a rule
debug(r)	Debug rule `r`
`r = p;`	Rule definition
`r %= p;`	Auto-rule definition. The attribute of `p` should be compatible with the synthesized attribute of `r`. When `p` is successful, its attribute is automatically propagated to `r`'s synthesized attribute.

`template <typename Iterator>`
`struct my_grammar : grammar<Iterat↵`
`or, A1, A2, A3>`
`{`
`  my_grammar() : my_gram↵`
`mar::base_type(start, name)`
`  {`
`  // Rule definitions`
`  start = /* ... */;`
`  }`
`  rule<Iterator, A1, A2, A3> start;`
`  // more rule declarations...`
`};`
	Grammar definition. `name` is an optional string that gives the grammar its name, useful for debugging and error handling.

`g.name(name)`	Naming a grammar
`g.name()`	Getting the name of a grammar

Semantic Actions

Has the form:

```
p[f]
```

where `f` is a function with the signatures:

```
void f(Attrib const&);
void f(Attrib const&, Context&);
void f(Attrib const&, Context&, bool&);
```

You can use Boost.Bind to bind member functions. For function objects, the allowed signatures are:

```
void operator()(Attrib const&, unused_type, unused_type) const;
void operator()(Attrib const&, Context&, unused_type) const;
void operator()(Attrib const&, Context&, bool&) const;
```

The `unused_type` is used in the signatures above to signify 'don't care'.

For more detailed information about semantic actions see: here.

Phoenix

Boost.Phoenix makes it easier to attach semantic actions. You just inline your lambda expressions:

```
p[phoenix-lambda-expression]
```

Spirit.Qi provides some Boost.Phoenix placeholders to important information from the `Attrib` and `Context` that are otherwise fiddly to extract.

Spirit.Qi specific Phoenix placeholders

`_1, _2... , _N`	Nth attribute of `p`
`_val`	The enclosing rule's synthesized attribute.
`_r1, _r2... , _rN`	The enclosing rule's Nth inherited attribute.
`_a, _b... , _j`	The enclosing rule's local variables (`_a` refers to the first).
`_pass`	Assign `false` to `_pass` to force a parser failure.

Important

All placeholders mentioned above are defined in the namespace `boost::spirit` and, for your convenience, are available in the namespace `boost::spirit::qi` as well.

For more detailed information about semantic actions see: here.

Reference

Parser Concepts

Spirit.Qi parsers fall into a couple of generalized concepts. The *Parser* is the most fundamental concept. All Spirit.Qi parsers are models of the *Parser* concept. *PrimitiveParser*, *UnaryParser*, *BinaryParser*, *NaryParser*, and *Nonterminal* are all refinements of the *Parser* concept.

The following sections provide details on these concepts.

Parser

Description

The *Parser* is the most fundamental concept. A Parser has a member function, `parse`, that accepts a first-last `ForwardIterator` pair andreturns bool as its result. The iterators delimit the data being parsed.function `parse`, that accepts a first-last `ForwardIterator` pair and returns `bool` as its result. The iterators delimit the data being parsed. The Parser's `parse` member function returns `true` if the parse succeeds, in which case the first iterator is advanced accordingly. Each Parser can represent a specific pattern or algorithm, or it can be a more complex parser formed as a composition of other Parsers.

Notation

`p`	A `Parser`.
`P`	A `Parser` type.
`Iter`	a `ForwardIterator` type.
`f`, `l`	`ForwardIterator`. first/last iterator pair.
`Context`	The parser's Context type.
`context`	The parser's Context, or `unused`.
`skip`	A skip Parser, or `unused`.
`attrib`	A Compatible Attribute, or `unused`.

Valid Expressions

In the expressions below, the behavior of the parser, `p`, and how `skip` and `attrib` are handled by `p`, are left unspecified in the base `Parser` concept. These are specified in subsequent, more refined concepts and by the actual models thereof.

For any Parser the following expressions must be valid:

Expression	Semantics	Return type
`p.parse(f, l, con↵ text, skip, attr)`	Match the input sequence starting from `f`. Return `true` if successful, otherwise return `false`.	`bool`
`p.what(context)`	Get information about a Parser.	`info`

Type Expressions

Expression	Description
`P::template attribute<Context, Iter>::type`	The Parser's expected attribute.
`traits::is_parser<P>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `P` is a Parser, `mpl::false_` otherwise (See MPL Boolean Constant).

Postcondition

Upon return from `p.parse` the following post conditions should hold:

- On a successful match, `f` is positioned one past the last matching character/token.

- On a failed match, if a `skip` parser is `unused`, `f` is restored to its original position prior to entry.
- On a failed match, if a `skip` parser is not `unused`, `f` is positioned one past the last character/token matching `skip`.
- On a failed match, `attrib` is left untouched.
- No post-skips: trailing `skip` characters/tokens will not be skipped.

Models

All parsers in Spirit.Qi are models of the *Parser* concept.

PrimitiveParser

Description

PrimitiveParser is the most basic building block that the client uses to build more complex parsers.

Refinement of

`Parser`

Pre-skip

Upon entry to the `parse` member function, a PrimitiveParser is required to do a pre-skip. Leading `skip` characters/tokens will be skipped prior to parsing. Only PrimitiveParsers are required to perform this pre-skip. This is typically carried out through a call to `qi::skip_over`:

```
qi::skip_over(f, l, skip);
```

Type Expressions

Expression	Description
`traits::is_primitive_parser<P>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `P`, is a PrimitiveParser, `mpl::false_` otherwise (See MPL Boolean Constant).

Models

- `attr(attrib)`
- `eoi`
- `eol`
- `eps`
- `symbols<Ch, T>`

UnaryParser

Description

UnaryParser is a composite parser that has a single subject. The UnaryParser may change the behavior of its subject following the Delegate Design Pattern.

Refinement of

`Parser`

Notation

`p` A UnaryParser.

`P` A UnaryParser type.

Valid Expressions

In addition to the requirements defined in `Parser`, for any UnaryParser the following must be met:

Expression	Semantics	Return type
`p.subject`	Subject parser.	`Parser`

Type Expressions

Expression	Description
`P::subject_type`	The subject parser type.
`traits::is_unary_parser<P>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `P` is a UnaryParser, `mpl::false_` otherwise (See MPL Boolean Constant).

Invariants

For any UnaryParser, `P`, the following invariant always holds:

- `traits::is_parser<P::subject_type>::type` evaluates to `mpl::true_`

Models

- And Predicate
- Kleene
- `lexeme`
- Not Predicate
- `omit`
- Plus
- `raw`
- `repeat`
- `skip`

BinaryParser

Description

BinaryParser is a composite parser that has a two subjects, `left` and `right`. The BinaryParser allows its subjects to be treated in the same way as a single instance of a `Parser` following the Composite Design Pattern.

Refinement of

`Parser`

Notation

`p` A BinaryParser.

`P` A BinaryParser type.

Valid Expressions

In addition to the requirements defined in `Parser`, for any BinaryParser the following must be met:

Expression	Semantics	Return type
`p.left`	Left parser.	`Parser`
`p.right`	Right parser.	`Parser`

Type Expressions

Expression	Description
`P::left_type`	The left parser type.
`P::right_type`	The right parser type.
`traits::is_binary_parser<P>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `P` is a BinaryParser, `mpl::false_` otherwise (See MPL Boolean Constant).

Invariants

For any BinaryParser, `P`, the following invariants always hold:

- `traits::is_parser<P::left_type>::type` evaluates to `mpl::true_`
- `traits::is_parser<P::right_type>::type` evaluates to `mpl::true_`

Models

- Difference
- List

NaryParser

Description

NaryParser is a composite parser that has one or more subjects. The NaryParser allows its subjects to be treated in the same way as a single instance of a `Parser` following the Composite Design Pattern.

Refinement of

`Parser`

Notation

`p` A NaryParser.

`P` A NaryParser type.

Valid Expressions

In addition to the requirements defined in `Parser`, for any NaryParser the following must be met:

Expression	Semantics	Return type
`p.elements`	The tuple of elements.	A Boost.Fusion Sequence of `Parser` types.

Type Expressions

Expression	Description
`p.elements_type`	Elements tuple type.
`traits::is_nary_parser<P>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `P` is a NaryParser, `mpl::false_` otherwise (See MPL Boolean Constant).

Invariants

For each element, `E`, in any NaryParser, `P`, the following invariant always holds:

- `traits::is_parser<E>::type` evaluates to `mpl::true_`

Models

- Alternative
- Expect
- Permutation
- Sequence
- Sequential Or

Nonterminal

Description

A Nonterminal is a symbol in a Parsing Expression Grammar production that represents a grammar fragment. Nonterminals may self reference to specify recursion. This is one of the most important concepts and the reason behind the word "recursive" in recursive descent parsing.

Refinement of

`Parser`

Signature

Nonterminals can have both synthesized and inherited attributes. The Nonterminal's *Signature* specifies both the synthesized and inherited attributes. The specification uses the function declarator syntax:

```
RT(A0, A1, A2, ..., AN)
```

where `RT` is the Nonterminal's synthesized attribute and `A0` ... `AN` are the Nonterminal's inherited attributes.

Attributes

The Nonterminal models a C++ function. The Nonterminal's synthesized attribute is analogous to the function return value and its inherited attributes are analogous to function arguments. The inherited attributes (arguments) can be passed in just like any Lazy Argument, e.g.:

```
r(expr) // Evaluate expr at parse time and pass the result to the Nonterminal r
```

_val

The `boost::spirit::qi::_val` placeholder can be used in Phoenix semantic actions anywhere in the Nonterminal's definition. This Phoenix placeholder refers to the Nonterminal's (synthesized) attribute. The `_val` placeholder acts like a mutable reference to the Nonterminal's attribute.

_r1 ... r10

The `boost::spirit::_r1` ... `boost::spirit::r10` placeholders can be used in Phoenix semantic actions anywhere in the Nonterminal's definition. These Phoenix placeholders refer to the Nonterminal's inherited attributes.

Locals

Nonterminals can have local variables that will be created on the stack at parse time. A locals descriptor added to the Nonterminal declaration will give the Nonterminal local variables:

```
template <typename T0, typename T1, typename T2, ..., typename TN>
struct locals;
```

where `T0` ... `TN` are the types of local variables accessible in your Phoenix semantic actions using the placeholders:

- `boost::spirit::_a`
- `boost::spirit::_b`
- `boost::spirit::_c`
- `boost::spirit::_d`
- `boost::spirit::_e`
- `boost::spirit::_f`
- `boost::spirit::_g`
- `boost::spirit::_h`
- `boost::spirit::_i`
- `boost::spirit::_j`

which correspond to the Nonterminal's local variables `T0` ... `T9`.

Notation

`x`	A Nonterminal
`X`	A Nonterminal type
`arg1`, `arg2`, ..., `argN`	Lazy Arguments that evaluate to each of the Nonterminal's inherited attributes.

Valid Expressions

In addition to the requirements defined in `Parser`, for any Nonterminal the following must be met:

Expression	Semantics	Return type
`x`	In a parser expression, invoke Nonterminal `x`	`X`
`x(arg1, arg2, ..., argN)`	In a parser expression, invoke Nonterminal `r` passing in inherited attributes `arg1` ... `argN`	`X`
`x.name(name)`	Naming a Nonterminal.	`void`
`x.name()`	Getting the name of a Nonterminal.	`std::string`
debug(x)	Debug Nonterminal `x`.	`void`

Type Expressions

Expression	Description
`X::sig_type`	The Signature of `X`: An MPL Forward Sequence. The first element is the Nonterminal's synthesized attribute type and the rest are the inherited attribute types.
`X::locals_type`	The local variables of `X`: An MPL Forward Sequence.

Models

- rule
- grammar

Basics

Lazy Argument

Some parsers (e.g. primitives and non-terminals) may take in additional attributes. Such parsers take the form:

```
p(a1, a2,..., aN)
```

where `p` is a parser. Each of the arguments (a1 ... aN) can either be an immediate value, or a function, `f`, with signature:

```
T f(Unused, Context)
```

where `T`, the function's return value, is compatible with the argument type expected and `Context` is the parser's Context type (The first argument is `unused` to make the `Context` the second argument. This is done for uniformity with Semantic Actions).

Character Encoding Namespace

Some parsers need to know which character set a `char` or `wchar_t` is operating on. For example, the `alnum` parser works differently with ISO8859.1 and ASCII encodings. Where necessary, Spirit encodes (tags) the parser with the character set.

We have a namespace for each character set Spirit will be supporting. That includes `ascii`, `iso8859_1`, `standard` and `standard_wide` (and in the future, `unicode`). In each of the character encoding namespaces, we place tagged versions of parsers such as `alnum`, `space` etc.

Example:

```
using boost::spirit::ascii::space; // use the ASCII space parser
```

Namespaces:

- boost::spirit::ascii
- boost::spirit::iso8859_1
- boost::spirit::standard
- boost::spirit::standard_wide

For ease of use, the components in this namespaces are also brought into the qi sub-namespaces with the same names:

- boost::spirit::qi::ascii
- boost::spirit::qi::iso8859_1
- boost::spirit::qi::standard
- boost::spirit::qi::standard_wide

Examples

All sections in the reference present some real world examples. The examples use a common test harness to keep the example code as minimal and direct to the point as possible. The test harness is presented below.

Some includes:

```
#include <boost/spirit/include/qi.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <iostream>
#include <string>
#include <cstdlib>
```

Our test functions:

These functions test the parsers without attributes.

```
template <typename P>
void test_parser(
    char const* input, P const& p, bool full_match = true)
{
    using boost::spirit::qi::parse;

    char const* f(input);
    char const* l(f + strlen(f));
    if (parse(f, l, p) && (!full_match || (f == l)))
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}

template <typename P>
void test_phrase_parser(
    char const* input, P const& p, bool full_match = true)
{
    using boost::spirit::qi::phrase_parse;
    using boost::spirit::qi::ascii::space;

    char const* f(input);
    char const* l(f + strlen(f));
    if (phrase_parse(f, l, p, space) && (!full_match || (f == l)))
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}
```

These functions test the parsers with user supplied attributes.

```
template <typename P, typename T>
void test_parser_attr(
    char const* input, P const& p, T& attr, bool full_match = true)
{
    using boost::spirit::qi::parse;

    char const* f(input);
    char const* l(f + strlen(f));
    if (parse(f, l, p, attr) && (!full_match || (f == l)))
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}

template <typename P, typename T>
void test_phrase_parser_attr(
    char const* input, P const& p, T& attr, bool full_match = true)
{
    using boost::spirit::qi::phrase_parse;
    using boost::spirit::qi::ascii::space;

    char const* f(input);
    char const* l(f + strlen(f));
    if (phrase_parse(f, l, p, space, attr) && (!full_match || (f == l)))
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}
```

The `print_info` utility function prints information contained in the `info` class.

```
struct printer
{
    typedef boost::spirit::utf8_string string;

    void element(string const& tag, string const& value, int depth) const
    {
        for (int i = 0; i < (depth*4); ++i) // indent to depth
            std::cout << ' ';

        std::cout << "tag: " << tag;
        if (value != "")
            std::cout << ", value: " << value;
        std::cout << std::endl;
    }
};

void print_info(boost::spirit::info const& what)
{
    using boost::spirit::basic_info_walker;

    printer pr;
    basic_info_walker<printer> walker(pr, what.tag, 0);
    boost::apply_visitor(walker, what.value);
}
```

String

Header

```
// forwards to <boost/spirit/home/support/string_traits.hpp>
#include <boost/spirit/support_string_traits.hpp>
```

A string can be any object `s`, of type, `S`, that satisfies the following expression traits:

Expression	Semantics
`boost::spirit::traits::is_string<S>`	Metafunction that evaluates to `mpl::true_` if a certain type, `S` is a string, `mpl::false_` otherwise (See MPL Boolean Constant).
`boost::spirit::traits::char_type_of<S>`	Metafunction that returns the underlying char type of a string type, `S`.
`boost::spirit::traits::get_c_string(s)`	Function that returns the underlying raw C-string from `s`.
`boost::spirit::traits::get_begin(s)`	Function that returns an STL iterator from `s` that points to the beginning the string.
`boost::spirit::traits::get_end(s)`	Function that returns an STL iterator from `s` that points to the end of the string.

Models

Predefined models include:

- any literal string, e.g. "Hello, World",
- a pointer/reference to a null-terminated array of characters

- a `std::basic_string<Char>`

The namespace `boost::spirit::traits` is open for users to provide their own specializations. The customization points implemented by *Spirit.Qi* usable to customize the behavior of parsers are described in the section Customization of Attribute Handling.

Parse API

Iterator Based Parse API

Description

The library provides a couple of free functions to make parsing a snap. These parser functions have two forms. The first form `parse` works on the character level. The second `phrase_parse` works on the phrase level and requires skip parser. Both versions can take in attributes by reference that will hold the parsed values on a successful parse.

Header

```
// forwards to <boost/spirit/home/qi/parse.hpp>
#include <boost/spirit/include/qi_parse.hpp>
```

For variadic attributes:

```
// forwards to <boost/spirit/home/qi/parse_attr.hpp>
#include <boost/spirit/include/qi_parse_attr.hpp>
```

The variadic attributes version of the API allows one or more attributes to be passed into the parse functions. The functions taking two or more are usable when the parser expression is a Sequence only. In this case each of the attributes passed have to match the corresponding part of the sequence.

Also, see Include Structure.

Namespace

Name
`boost::spirit::qi::parse`
`boost::spirit::qi::phrase_parse`
`boost::spirit::qi::skip_flag::postskip`
`boost::spirit::qi::skip_flag::dont_postskip`

Synopsis

```
template <typename Iterator, typename Expr>
inline bool
parse(
    Iterator& first
  , Iterator last
  , Expr const& expr);

template <typename Iterator, typename Expr
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline bool
parse(
    Iterator& first
  , Iterator last
  , Expr const& expr
  , Attr1& attr1, Attr2& attr2, ..., AttrN& attrN);

template <typename Iterator, typename Expr, typename Skipper>
inline bool
phrase_parse(
    Iterator& first
  , Iterator last
  , Expr const& expr
  , Skipper const& skipper
  , BOOST_SCOPED_ENUM(skip_flag) post_skip = skip_flag::postskip);

template <typename Iterator, typename Expr, typename Skipper
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline bool
phrase_parse(
    Iterator& first
  , Iterator last
  , Expr const& expr
  , Skipper const& skipper
  , Attr1& attr1, Attr2& attr2, ..., AttrN& attrN);

template <typename Iterator, typename Expr, typename Skipper
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline bool
phrase_parse(
    Iterator& first
  , Iterator last
  , Expr const& expr
  , Skipper const& skipper
  , BOOST_SCOPED_ENUM(skip_flag) post_skip
  , Attr1& attr1, Attr2& attr2, ..., AttrN& attrN);
```

All functions above return `true` if none of the involved parser components failed, and `false` otherwise.

The maximum number of supported arguments is limited by the preprocessor constant `SPIRIT_ARGUMENTS_LIMIT`. This constant defaults to the value defined by the preprocessor constant `PHOENIX_LIMIT` (which in turn defaults to `10`).

Note

The variadic function with two or more attributes internally combine references to all passed attributes into a `fusion::vector` and forward this as a combined attribute to the corresponding one attribute function.

The `phrase_parse` functions not taking an explicit `skip_flag` as one of their arguments invoke the passed skipper after a successful match of the parser expression. This can be inhbited by using the other versions of that function while passing `skip_flag::dont_postskip` to the corresponding argument.

Parameter	Description
`Iterator`	`ForwardIterator` pointing to the source to parse.
`Expr`	An expression that can be converted to a Qi parser.
`Skipper`	Parser used to skip white spaces.
`Attr1`, `Attr2`, ..., `AttrN`	One or more attributes.

Stream Based Parse API

Description

The library provides a couple of Standard IO Manipulators allowing to integrate *Spirit.Qi* input parsing facilities with Standard input streams. These parser manipulators have two forms. The first form, `match`, works on the character level. The second `phrase_match` works on the phrase level and requires a skip parser. Both versions can take in attributes by reference that will hold the parsed values on a successful parse.

Header

```
// forwards to <boost/spirit/home/qi/stream/match_manip.hpp>
#include <boost/spirit/include/qi_match.hpp>
```

For variadic attributes:

```
// forwards to <boost/spirit/home/qi/stream/match_manip_attr.hpp>
#include <boost/spirit/include/qi_match_attr.hpp>
```

The variadic attributes version of the API allows one or more attributes to be passed into the parse manipulators. The manipulators taking two or more attributes are usable when the parser expression is a Sequence only. In this case each of the attributes passed have to match the corresponding part of the sequence.

Also, see Include Structure.

Namespace

Name
`boost::spirit::qi::match`
`boost::spirit::qi::match_delimited`
`boost::spirit::qi::skip_flag::postskip`
`boost::spirit::qi::skip_flag::dont_postskip`

Synopsis

```
template <typename Expr>
inline <unspecified>
match(
    Expr const& xpr);

template <typename Expr
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline <unspecified>
match(
    Expr const& xpr
  , Attr1& attr1, Attr2& attr2, ..., AttrN& attrN);

template <typename Expr, typename Skipper>
inline <unspecified>
phrase_match(
    Expr const& expr
  , Skipper const& s
  , BOOST_SCOPED_ENUM(skip_flag) post_skip = skip_flag::postskip);

template <typename Expr, typename Skipper
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline <unspecified>
phrase_match(
    Expr const& expr
  , Skipper const& s
  , Attr1& attr1, Attr2& attr2, ..., AttrN& attrN);

template <typename Expr, typename Skipper
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline <unspecified>
phrase_match(
    Expr const& expr
  , Skipper const& s
  , BOOST_SCOPED_ENUM(skip_flag) post_skip
  , Attr1& attr1, Attr2& attr2, ..., AttrN& attrN);
```

All functions above return a standard IO stream manipulator instance (see Manipulators), which when streamed from an input stream will result in parsing the input using the embedded *Spirit.Qi* parser expression. Any error (or failed parse) occuring during the invocation of the *Spirit.Qi* parsers will be reflected in the streams status flag (`std::ios_base::failbit` will be set).

The maximum number of supported arguments is limited by the preprocessor constant `SPIRIT_ARGUMENTS_LIMIT`. This constant defaults to the value defined by the preprocessor constant `PHOENIX_LIMIT` (which in turn defaults to `10`).

Note

The variadic manipulators with two or more attributes internally combine references to all passed attributes into a `fusion::vector` and forward this as a combined attribute to the corresponding manipulator taking one attribute.

The `phrase_match` manipulators not taking an explicit `skip_flag` as one of their arguments invoke the passed skipper after a successful match of the parser expression. This can be inhbited by using the other versions of that manipulator while passing `skip_flag::dont_postskip` to the corresponding argument.

Template parameters

Parameter	Description
`Expr`	An expression that can be converted to a Qi parser.
`Skipper`	Parser used to skip white spaces.
`Attr1`, `Attr2`, ..., `AttrN`	One or more attributes.

Action

Description

Semantic actions may be attached to any point in the grammar specification. They allow to call a function or function object in order to provide the value to be output by the parser the semantic action is attached to. Semantic actions are associated with a parser using the syntax `p[]`, where `p` is an arbitrary parser expression.

Header

```
// forwards to <boost/spirit/home/qi/action.hpp>
#include <boost/spirit/include/qi_action.hpp>
```

Also, see Include Structure.

Model of

`UnaryParser`

Notation

`a`, `p`	Instances of a parser, `P`
`A`	Attribute type exposed by a parser, `a`
`fa`	A (semantic action) function with signature `void(Attrib&, Context, bool&)`. The third parameter is a boolean flag that can be set to false to force the parser to fail. Both `Context` and the boolean flag are optional. For more information see below.
`Attrib`	The attribute obtained from the parse.
`Context`	The type of the parser execution context. For more information see below.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`p[fa]`	If `p` is successful, call semantic action, `fa`. The function or function object `fa` is provided the attribute value parsed by the parser `p`, plus some more context information and a mutable bool flag which can be used to fail parsing.

The possible signatures for functions to be used as semantic actions are:

```
template <typename Attrib>
void fa(Attrib& attr);

template <typename Attrib, typename Context>
void fa(Attrib& attr, Context& context);

template <typename Attrib, typename Context>
void fa(Attrib& attr, Context& context, bool& pass);
```

The function or function object is expected to return the value to generate output from by assigning it to the first parameter, `attr`. Here `Attrib` is the attribute type of the parser the semantic action is attached to.

The type `Context` is the type of the parser execution context. This type is unspecified and depends on the context the parser is invoked in. The value, `context` used by semantic actions written using Phoenix to access various context dependent attributes and values. For more information about Phoenix placeholder expressions usable in semantic actions see `Nonterminal`.

The third parameter, `pass`, can be used by the semantic action to force the associated parser to fail. If pass is set to `false` the action parser will immediately return `false` as well, while not invoking `p` and not generating any output.

Attributes

Expression	Attribute
`a[fa]`	`a: A --> a[fa]: A`

Complexity

The complexity of the action parser is defined by the complexity of the parser the semantic action is attached to and the complexity of the function or function object used as the semantic action.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

[reference_qi_action]

More examples for semantic actions can be found here: Examples of Semantic Actions.

Auxiliary

This module includes different auxiliary parsers not fitting into any of the other categories. This module includes the `attr`, `attr_cast`, `eoi`, `eol`, `eps`, and `lazy` parsers.

Module Header

```
// forwards to <boost/spirit/home/qi/auxiliary.hpp>
#include <boost/spirit/include/qi_auxiliary.hpp>
```

Also, see Include Structure.

Attribute (`attr`)

Description

The Attribute parser does not consume any input, for this reason it always matches an empty string and always succeeds. It's purpose is to expose its specified parameter as an attribute.

Header

```
// forwards to <boost/spirit/home/qi/auxiliary/attr.hpp>
#include <boost/spirit/include/qi_attr.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::attr // alias: boost::spirit::qi::attr`

Model of

`PrimitiveParser`

Notation

a A arbitrary typed constant value, e.g. 0.0, "Hello", or a variable of arbitrary type or a Lazy Argument that evaluates to an arbitrary type.

A The type of a or if it is a Lazy Argument, its return type.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`attr(a)`	Create a pseudo parser exposing the current value of a as its attribute without consuming any input at parse time.

Attributes

Expression	Attribute
`attr(a)`	A

Complexity

O(1)

The complexity is constant as no input is consumed and no matching is done.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
namespace phx = boost::phoenix;
using boost::spirit::qi::attr;
```

Using `attr` with literals:

```
std::string str;
test_parser_attr("", attr("boost"), str);
std::cout << str << std::endl;            // will print 'boost'

double d;
test_parser_attr("", attr(1.0), d);
std::cout << d << std::endl;              // will print '1.0'
```

Using `attr` with Phoenix function objects:

```
d = 0.0;
double d1 = 1.2;
test_parser_attr("", attr(phx::ref(d1)), d);
std::cout << d << std::endl;              // will print '1.2'
```

Attribute Transformation Pseudo Generator (`attr_cast`)

Description

The `attr_cast<Exposed, Transformed>()` component invokes the embedded parser while supplying an attribute of type `Transformed`. The supplied attribute gets created from the original attribute (of type `Exposed`) passed to this component using the customization point `transform_attribute`.

Header

```
// forwards to <boost/spirit/home/qi/auxiliary/attr_cast.hpp>
#include <boost/spirit/include/qi_attr_cast.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::attr_cast // alias: boost::spirit::qi::attr_cast`

Synopsis

```
template <Exposed, Transformed>
<unspecified> attr_cast(<unspecified>);
```

Template parameters

Parameter	Description	Default
`Exposed`	The type of the attribute supplied to the `attr_cast`.	`unused_type`
`Transformed`	The type of the attribute expected by the embedded parser `p`.	`unused_type`

The `attr_cast` is a function template. It is possible to invoke it using the following schemes:

```
attr_cast(p)
attr_cast<Exposed>(p)
attr_cast<Exposed, Transformed>(p)
```

depending on which of the attribute types can be deduced properly if not explicitly specified.

Model of

`UnaryParser`

Notation

`p` A parser object.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`attr_cast(p)`	Create a component invoking the parser `p` while passing an attribute of the type as normally expected by `p`. The type of the supplied attribute will be transformed to the type `p` exposes as its attribute type (by using the attribute customization point `transform_attribute`).
`attr_cast<Exposed>(p)`	Create a component invoking the parser `p` while passing an attribute of the type as normally expected by `p`. The supplied attribute is expected to be of the type `Exposed`, it will be transformed to the type `p` exposes as its attribute type (using the attribute customization point `transform_attribute`).
`attr_cast<Exposed, Transformed>(p)`	Create a component invoking the parser `p` while passing an attribute of type `Transformed`. The supplied attribute is expected to be of the type `Exposed`, it will be transformed to the type `Transformed` (using the attribute customization point `transform_attribute`).

Attributes

Expression	Attribute
`attr_cast(p)`	`p: A --> attr_cast(p): A`
`attr_cast<Exposed>(p)`	`p: A --> attr_cast<Exposed>(p): Exposed`
`attr_cast<Exposed, Transformed>(p)`	`p: A --> attr_cast<Exposed, Transformed>(p): Exposed`

Complexity

The complexity of this component is fully defined by the complexity of the embedded parser `p`.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::int_;
```

The example references data structure `int_data` which needs a specialization of the customization point `transform_attribute`:

```
// this is just a test structure we want to use in place of an int
struct int_data
{
    int i;
};


// we provide a custom attribute transformation to allow its use as an int
namespace boost { namespace spirit { namespace traits
{
    // in this case we just expose the embedded 'int' as the attribute instance
    // to use, allowing to leave the function 'post()' empty
    template <>
    struct transform_attribute<int_data, int>
    {
        typedef int& type;
        static int& pre(int_data& d) { return d.i; }
        static void post(int_data& val, int const& attr) {}
    };
}}}
```

Now we use the `attr_cast` pseudo parser to invoke the attribute transformation:

```
int_data d = { 0 };
test_parser_attr("1", boost::spirit::qi::attr_cast(int_), d);
std::cout << d.i << std::endl;
```

End of Line (`eol`)

Description

The `eol` parser matches the end of line (CR/LF and combinations thereof).

Header

```
// forwards to <boost/spirit/home/qi/auxiliary/eol.hpp>
#include <boost/spirit/include/qi_eol.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::eol // alias: boost::spirit::qi::eol`

Model of

`PrimitiveParser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`eol`	Create a parser that matches the end of line.

Attributes

Expression	Attribute
`eol`	`unused`

Complexity

O(1)

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::eol;
```

Using `eol`:

```
test_parser("\n", eol);
```

End of Input (`eoi`)

Description

The `eoi` parser matches the end of input (returns a sucessful match with 0 length when the input is exhausted)

Header

```
// forwards to <boost/spirit/home/qi/auxiliary/eoi.hpp>
#include <boost/spirit/include/qi_eoi.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::eoi // alias: boost::spirit::qi::eoi`

Model of

`PrimitiveParser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`eoi`	Create a parser that matches the end of input.

Attributes

Expression	Attribute
`eoi`	`unused`

Complexity

O(1)

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::eoi;
```

Using `eoi`:

```
test_parser("", eoi);
```

Epsilon (`eps`)

Description

The Epsilon (`eps`) is a multi-purpose parser that returns a zero length match.

Simple Form

In its simplest form, `eps` matches the null string and always returns a match of zero length:

```
eps // always returns a zero-length match
```

This form is usually used to trigger a semantic action unconditionally. For example, it is useful in triggering error messages when a set of alternatives fail:

```
r = a | b | c | eps[error()]; // Call error if a, b, and c fail to match
```

Semantic Predicate

Semantic predicates allow you to attach a conditional function anywhere in the grammar. In this role, the epsilon takes a Lazy Argument that returns `true` or `false`. The Lazy Argument is typically a test that is called to resolve ambiguity in the grammar. A parse failure will be reported when the Lazy Argument result evaluates to `false`. Otherwise an empty match will be reported. The general form is:

```
eps(f) >> rest;
```

The Lazy Argument `f` is called to do a semantic test (say, checking if a symbol is in the symbol table). If test returns true, `rest` will be evaluated. Otherwise, the production will return early with a no-match without ever touching rest.

Header

```
// forwards to <boost/spirit/home/qi/auxiliary/eps.hpp>
#include <boost/spirit/include/qi_eps.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::eps // alias: boost::spirit::qi::eps`

Model of

`PrimitiveParser`

Notation

`f` A Lazy Argument that evaluates `bool`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`eps`	Match an empty string (always matches).
`eps(f)`	If `f` evaluates to `true`, return a zero length match.

Attributes

Expression	Attribute
`eps`	`unused`

Complexity

For plain (`eps`) the complexity is O(1). For Semantic predicates (`eps(f)`) the complexity is defined by the function `f`.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::eps;
using boost::spirit::qi::int_;
using boost::spirit::qi::_1;
namespace phx = boost::phoenix;
```

Basic `eps`:

```
test_parser("", eps); // always matches
```

This example simulates the "classic" `if_p` parser. Here, `int_` will be tried only if the condition, `c`, is true.

```
bool c = true; // a flag
test_parser("1234", eps(phx::ref(c) == true) >> int_);
```

This example simulates the "classic" `while_p` parser. Here, the kleene loop will exit once the condition, c, becomes true. Notice that the condition, `c, is turned to` false `when we get to parse 4`.

```
test_phrase_parser("1 2 3 4",
    *(eps(phx::ref(c) == true) >> int_[phx::ref(c) = (_1 == 4)]));
```

Lazy (`lazy`)

Description

The `lazy` parser, as its name suggests, invokes a lazy Phoenix function that returns a parser at parse time. This parser will be used once it is created to continue the parse.

Header

```
// forwards to <boost/spirit/home/qi/auxiliary/lazy.hpp>
#include <boost/spirit/include/qi_lazy.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lazy // alias: boost::spirit::qi::lazy`

Model of

`Parser`

Notation

`fp` A Lazy Argument that evaluates to a `Parser`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `Parser`.

Expression	Semantics
`fp`	Create a lazy-parser from a Lazy Argument, `fp`. `fp` will be invoked at parse time. `fp` is expected to return a `Parser` object. This parser is then invoked in order to parse the input.
`lazy(fp)`	Create a lazy-parser from a Lazy Argument, `fp`. `fp` will be invoked at parse time. `fp` is expected to return a `Parser` object. This parser is then invoked in order to parse the input.

Attributes

Expression	Attribute
`fp`	The attribute type of the return type of `fp`.
`lazy(fp)`	The attribute type of the return type of `fp`.

Complexity

The complexity of the `lazy` parser is determined by the complexity of the parser returned from `fp`.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::lazy;
using boost::spirit::ascii::string;
using boost::phoenix::val;
```

Using `lazy`:

Here, the phoenix::val expression creates a function that returns its argument when invoked. The lazy expression defers the invocation of this function at parse time. Then, this parser (string parser) is called into action. All this takes place at parse time.

```
test_parser("Hello", lazy(val(string("Hello"))));
```

The above is equivalent to:

```
test_parser("Hello", val(string("Hello")));
```

Binary

This module includes different parsers for parsing binary data in various endianness. It includes parsers for default (native), little, and big endian binary input.

Module Header

```
// forwards to <boost/spirit/home/qi/binary.hpp>
#include <boost/spirit/include/qi_binary.hpp>
```

Also, see Include Structure.

Binary Native Endian

Description

Binary native endian parsers are designed to parse binary byte streams that are laid out in the native endianness of the target architecture.

Header

```
// forwards to <boost/spirit/home/qi/binary.hpp>
#include <boost/spirit/include/qi_binary.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::byte_ // alias: boost::spirit::qi::byte_`
`boost::spirit::word // alias: boost::spirit::qi::word`
`boost::spirit::dword // alias: boost::spirit::qi::dword`
`boost::spirit::qword // alias: boost::spirit::qi::qword`

Note

`qword` is only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `unsigned long long` (64 bit) integer types).

Model of

`PrimitiveParser`

Notation

`b` A single byte (8 bit binary value) or a Lazy Argument that evaluates to a single byte. This value is always in native endian.

`w` A 16 bit binary value or a Lazy Argument that evaluates to a 16 bit binary value. This value is always in native endian.

`dw` A 32 bit binary value or a Lazy Argument that evaluates to a 32 bit binary value. This value is always in native endian.

`qw` A 64 bit binary value or a Lazy Argument that evaluates to a 64 bit binary value. This value is always in native endian.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Description
`byte_`	Matches any 8 bit native endian binary.
`word`	Matches any 16 bit native endian binary.
`dword`	Matches any 32 bit native endian binary.
`qword`	Matches any 64 bit native endian binary.
`byte_(b)`	Matches an exact 8 bit native endian binary.
`word(w)`	Matches an exact 16 bit native endian binary.
`dword(dw)`	Matches an exact 32 bit native endian binary.
`qword(qw)`	Matches an exact 64 bit native endian binary.

Attributes

Expression	Attribute
byte_	boost::uint_least8_t
word	boost::uint_least16_t
dword	boost::uint_least32_t
qword	boost::uint_least64_t
byte_(b)	unused
word(w)	unused
dword(dw)	unused
qword(qw)	unused

Complexity

O(N), where N is the number of bytes parsed

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Using declarations and variables:

```
using boost::spirit::qi::byte_;
using boost::spirit::qi::word;
using boost::spirit::qi::dword;
using boost::spirit::qi::qword;

boost::uint8_t uc;
boost::uint16_t us;
boost::uint32_t ui;
boost::uint64_t ul;
```

Basic usage of the native binary parsers for little endian platforms:

```
test_parser_attr("\x01", byte_, uc); assert(uc == 0x01);
test_parser_attr("\x01\x02", word, us); assert(us == 0x0201);
test_parser_attr("\x01\x02\x03\x04", dword, ui); assert(ui == 0x04030201);
test_parser_attr("\x01\x02\x03\x04\x05\x06\x07\x08", qword, ul);
assert(ul == 0x0807060504030201LL);

test_parser("\x01", byte_(0x01));
test_parser("\x01\x02", word(0x0201));
test_parser("\x01\x02\x03\x04", dword(0x04030201));
test_parser("\x01\x02\x03\x04\x05\x06\x07\x08",
    qword(0x0807060504030201LL));
```

Basic usage of the native binary parsers for big endian platforms:

```
test_parser_attr("\x01", byte_, uc); assert(uc == 0x01);
test_parser_attr("\x01\x02", word, us); assert(us ==  0x0102);
test_parser_attr("\x01\x02\x03\x04", dword, ui); assert(ui == 0x01020304);
test_parser_attr("\x01\x02\x03\x04\x05\x06\x07\x08", qword, ul);
assert(0x0102030405060708LL);

test_parser("\x01", byte_(0x01));
test_parser("\x01\x02", word(0x0102));
test_parser("\x01\x02\x03\x04", dword(0x01020304));
test_parser("\x01\x02\x03\x04\x05\x06\x07\x08",
    qword(0x0102030405060708LL));
```

Binary Little Endian

Description

Binary little endian parsers are designed to parse binary byte streams that are laid out in little endian.

Header

```
// forwards to <boost/spirit/home/qi/binary.hpp>
#include <boost/spirit/include/qi_binary.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::little_word // alias: boost::spirit::qi::little_word`
`boost::spirit::little_dword // alias: boost::spirit::qi::little_dword`
`boost::spirit::little_qword // alias: boost::spirit::qi::little_qword`

Note

`little_qword` is only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `unsigned long long` (64 bit) integer types).

Model of

`PrimitiveParser`

Notation

`w` A 16 bit binary value or a Lazy Argument that evaluates to a 16 bit binary value. This value is always in native endian.

`dw` A 32 bit binary value or a Lazy Argument that evaluates to a 32 bit binary value. This value is always in native endian.

`qw` A 64 bit binary value or a Lazy Argument that evaluates to a 64 bit binary value. This value is always in native endian.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Description
`little_word`	Matches any 16 bit little endian binary.
`little_dword`	Matches any 32 bit little endian binary.
`little_qword`	Matches any 64 bit little endian binary.
`little_word(w)`	Matches an exact 16 bit little endian binary.
`little_dword(dw)`	Matches an exact 32 bit little endian binary.
`little_qword(qw)`	Matches an exact 32 bit little endian binary.

Attributes

Expression	Attribute
`little_word`	`boost::uint_least16_t`
`little_dword`	`boost::uint_least32_t`
`little_qword`	`boost::uint_least64_t`
`little_word(w)`	`unused`
`little_dword(dw)`	`unused`
`little_qword(qw)`	`unused`

Complexity

O(N), where N is the number of bytes parsed

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Using declarations and variables:

```
using boost::spirit::qi::little_word;
using boost::spirit::qi::little_dword;
using boost::spirit::qi::little_qword;

boost::uint8_t uc;
boost::uint16_t us;
boost::uint32_t ui;
boost::uint64_t ul;
```

Basic usage of the little endian binary parsers:

```
test_parser_attr("\x01\x02", little_word, us); assert(us == 0x0201);
test_parser_attr("\x01\x02\x03\x04", little_dword, ui); assert(ui == 0x04030201);
test_parser_attr("\x01\x02\x03\x04\x05\x06\x07\x08", little_qword, ul);
assert(ul == 0x0807060504030201LL);

test_parser("\x01\x02", little_word(0x0201));
test_parser("\x01\x02\x03\x04", little_dword(0x04030201));
test_parser("\x01\x02\x03\x04\x05\x06\x07\x08",
    little_qword(0x0807060504030201LL));
```

Binary Big Endian

Description

Binary big endian parsers are designed to parse binary byte streams that are laid out in big endian.

Header

```
// forwards to <boost/spirit/home/qi/binary.hpp>
#include <boost/spirit/include/qi_binary.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::big_word // alias: boost::spirit::qi::big_word`
`boost::spirit::big_dword // alias: boost::spirit::qi::big_dword`
`boost::spirit::big_qword // alias: boost::spirit::qi::big_qword`

Note

`big_qword` is only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `unsigned long long` (64 bit) integer types).

Model of

`PrimitiveParser`

Notation

`w` A 16 bit binary value or a Lazy Argument that evaluates to a 16 bit binary value. This value is always in native endian.

`dw` A 32 bit binary value or a Lazy Argument that evaluates to a 32 bit binary value. This value is always in native endian.

`qw` A 64 bit binary value or a Lazy Argument that evaluates to a 64 bit binary value. This value is always in native endian.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Description
`big_word`	Matches any 16 bit big endian binary.
`big_dword`	Matches any 32 bit big endian binary.
`big_qword`	Matches any 64 bit big endian binary.
`big_word(w)`	Matches an exact 16 bit big endian binary.
`big_dword(dw)`	Matches an exact 32 bit big endian binary.
`big_qword(qw)`	Matches an exact 32 bit big endian binary.

Attributes

Expression	Attribute
`big_word`	`boost::uint_least16_t`
`big_dword`	`boost::uint_least32_t`
`big_qword`	`boost::uint_least64_t`
`big_word(w)`	`unused`
`big_dword(dw)`	`unused`
`big_qword(qw)`	`unused`

Complexity

O(N), where N is the number of bytes parsed

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Using declarations and variables:

```
using boost::spirit::qi::big_word;
using boost::spirit::qi::big_dword;
using boost::spirit::qi::big_qword;

boost::uint8_t uc;
boost::uint16_t us;
boost::uint32_t ui;
boost::uint64_t ul;
```

Basic usage of the big endian binary parsers:

```
test_parser_attr("\x01\x02", big_word, us); assert(us ==  0x0102);
test_parser_attr("\x01\x02\x03\x04", big_dword, ui); assert(ui == 0x01020304);
test_parser_attr("\x01\x02\x03\x04\x05\x06\x07\x08", big_qword, ul);
assert(0x0102030405060708LL);

test_parser("\x01\x02", big_word(0x0102));
test_parser("\x01\x02\x03\x04", big_dword(0x01020304));
test_parser("\x01\x02\x03\x04\x05\x06\x07\x08",
    big_qword(0x0102030405060708LL));
```

Char

This module includes parsers for single characters. Currently, this module includes literal chars (e.g. `'x'`, `L'x'`), `char_` (single characters, ranges and character sets) and the encoding specific character classifiers (`alnum`, `alpha`, `digit`, `xdigit`, etc.).

Module Header

```
// forwards to <boost/spirit/home/qi/char.hpp>
#include <boost/spirit/include/qi_char.hpp>
```

Also, see Include Structure.

Char (`char_`, `lit`)

Description

The `char_` parser matches single characters. The `char_` parser has an associated Character Encoding Namespace. This is needed when doing basic operations such as inhibiting case sensitivity and dealing with character ranges.

There are various forms of `char_`.

char_

The no argument form of `char_` matches any character in the assocaiated Character Encoding Namespace.

```
char_               // matches any character
```

char_(ch)

The single argument form of `char_` (with a character argument) matches the supplied character.

```
char_('x')          // matches 'x'
char_(L'x')         // matches L'x'
char_(x)            // matches x (a char)
```

char_(first, last)

`char_` with two arguments, matches a range of characters.

```
char_('a','z')      // alphabetic characters
char_(L'0',L'9')    // digits
```

A range of characters is created from a low-high character pair. Such a parser matches a single character that is in the range, including both endpoints. Note, the first character must be *before* the second, according to the underlying Character Encoding Namespace.

Character mapping is inherently platform dependent. It is not guaranteed in the standard for example that `'A' < 'Z'`, that is why in Spirit2, we purposely attach a specific Character Encoding Namespace (such as ASCII, ISO-8859-1) to the `char_` parser to eliminate such ambiguities.

Note

Sparse bit vectors

To accomodate 16/32 and 64 bit characters, the char-set statically switches from a `std::bitset` implementation when the character type is not greater than 8 bits, to a sparse bit/boolean set which uses a sorted vector of disjoint ranges (`range_run`). The set is constructed from ranges such that adjacent or overlapping ranges are coalesced.

`range_runs` are very space-economical in situations where there are lots of ranges and a few individual disjoint values. Searching is O(log n) where n is the number of ranges.

char_(def)

Lastly, when given a string (a plain C string, a `std::basic_string`, etc.), the string is regarded as a char-set definition string following a syntax that resembles posix style regular expression character sets (except that double quotes delimit the set elements instead of square brackets and there is no special negation ^ character). Examples:

```
char_("a-zA-Z")      // alphabetic characters
char_("0-9a-fA-F")   // hexadecimal characters
char_("actgACTG")    // DNA identifiers
char_("\x7f\x7e")    // Hexadecimal 0x7F and 0x7E
```

lit(ch)

`lit`, when passed a single character, behaves like the single argument `char_` except that `lit` does not synthesize an attribute. A plain `char` or `wchar_t` is equivalent to a `lit`.

Note

`lit` is reused by both the string parsers and the char parsers. In general, a char parser is created when you pass in a character and a string parser is created when you pass in a string. The exception is when you pass a single element literal string, e.g. `lit("x")`. In this case, we optimize this to create a char parser instead of a string parser.

Examples:

```
'x'
lit('x')
lit(L'x')
lit(c) // c is a char
```

Header

```
// forwards to <boost/spirit/home/qi/char/char.hpp>
#include <boost/spirit/include/qi_char_.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lit // alias: boost::spirit::qi::lit`
`ns::char_`

In the table above, `ns` represents a Character Encoding Namespace.

Model of

`PrimitiveParser`

Notation

`c`, `f`, `l` — A literal char, e.g. `'x'`, `L'x'` or anything that can be converted to a `char` or `wchar_t`, or a Lazy Argument that evaluates to anything that can be converted to a `char` or `wchar_t`.

`ns` — A Character Encoding Namespace.

`cs` — A String or a Lazy Argument that evaluates to a String that specifies a char-set definition string following a syntax that resembles posix style regular expression character sets (except the square brackets and the negation `^` character).

`cp` — A char parser, a char range parser or a char set parser.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`c`	Create char parser from a char, `c`.
`lit(c)`	Create a char parser from a char, `c`.
`ns::char_`	Create a char parser that matches any character in the `ns` encoding.
`ns::char_(c)`	Create a char parser with `ns` encoding from a char, `c`.
`ns::char_(f, l)`	Create a char-range parser that matches characters from range (`f` to `l`, inclusive) with `ns` encoding.
`ns::char_(cs)`	Create a char-set parser with `ns` encoding from a char-set definition string, `cs`.
`~cp`	Negate `cp`. The result is a negated char parser that matches any character in the `ns` encoding except the characters matched by `cp`.

Attributes

Expression	Attribute
`c`	`unused` or if `c` is a Lazy Argument, the character type returned by invoking it.
`lit(c)`	`unused` or if `c` is a Lazy Argument, the character type returned by invoking it.
`ns::char_`	The character type of the Character Encoding Namespace, `ns`.
`ns::char_(c)`	The character type of the Character Encoding Namespace, `ns`.
`ns::char_(f, l)`	The character type of the Character Encoding Namespace, `ns`.
`ns::char_(cs)`	The character type of the Character Encoding Namespace, `ns`.
`~cp`	The attribute of `cp`.

Complexity

O(N), except for char-sets with 16-bit (or more) characters (e.g. `wchar_t`). These have **O(log N)** complexity, where N is the number of distinct character ranges in the set.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::lit;
using boost::spirit::ascii::char_;
```

Basic literals:

```
test_parser("x", 'x');                  // plain literal
test_parser("x", lit('x'));             // explicit literal
test_parser("x", char_('x'));           // ascii::char_
```

Range:

```
char ch;
test_parser_attr("5", char_('0','9'), ch);  // ascii::char_ range
std::cout << ch << std::endl;               // prints '5'
```

Character set:

```
test_parser_attr("5", char_("0-9"), ch);    // ascii::char_ set
std::cout << ch << std::endl;               // prints '5'
```

Lazy char_ using Phoenix

```
namespace phx = boost::phoenix;
test_parser("x", phx::val('x'));            // direct
test_parser("5",
    char_(phx::val('0'),phx::val('9')));    // ascii::char_ range
```

Char Classification (`alnum`, `digit`, etc.)

Description

The library has the full repertoire of single character parsers for character classification. This includes the usual `alnum`, `alpha`, `digit`, `xdigit`, etc. parsers. These parsers have an associated Character Encoding Namespace. This is needed when doing basic operations such as inhibiting case sensitivity.

Header

```
// forwards to <boost/spirit/home/qi/char/char_class.hpp>
#include <boost/spirit/include/qi_char_class.hpp>
```

Also, see Include Structure.

Namespace

Name
`ns::alnum`
`ns::alpha`
`ns::blank`
`ns::cntrl`
`ns::digit`
`ns::graph`
`ns::lower`
`ns::print`
`ns::punct`
`ns::space`
`ns::upper`
`ns::xdigit`

In the table above, `ns` represents a Character Encoding Namespace.

Model of

`PrimitiveParser`

Notation

`ns` A Character Encoding Namespace.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`ns::alnum`	Matches alpha-numeric characters
`ns::alpha`	Matches alphabetic characters
`ns::blank`	Matches spaces or tabs
`ns::cntrl`	Matches control characters
`ns::digit`	Matches numeric digits
`ns::graph`	Matches non-space printing characters
`ns::lower`	Matches lower case letters
`ns::print`	Matches printable characters
`ns::punct`	Matches punctuation symbols
`ns::space`	Matches spaces, tabs, returns, and newlines
`ns::upper`	Matches upper case letters
`ns::xdigit`	Matches hexadecimal digits

Attributes

The character type of the Character Encoding Namespace, `ns`.

Complexity

O(N)

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::alnum;
using boost::spirit::ascii::blank;
using boost::spirit::ascii::digit;
using boost::spirit::ascii::lower;
```

Basic usage:

```
test_parser("1", alnum);
test_parser(" ", blank);
test_parser("1", digit);
test_parser("a", lower);
```

Directive

This module includes different directives usable to augment and parametrize other parsers. It includes the `no_case`, `lexeme`, `omit`, `raw`, `repeat`, and `skip` directives.

Module Header

```
// forwards to <boost/spirit/home/qi/directive.hpp>
#include <boost/spirit/include/qi_directive.hpp>
```

Also, see Include Structure.

Inhibiting Skipping (`lexeme[]`)

Description

The `lexeme[]` directive turns off white space skipping. At the phrase level, the parser ignores white spaces, possibly including comments. Use `lexeme` in situations where you want to work at the character level instead of the phrase level. Parsers can be made to work at the character level by enclosing the pertinent parts inside the `lexeme` directive. For example, here's a rule that parses integers:

```
integer = lexeme[ -(lit('+') | '-') >> +digit ];
```

The `lexeme` directive instructs its subject parser to work on the character level. Without it, the `integer` rule would have allowed erroneous embedded white spaces in inputs such as `"1 2 345"` which will be parsed as `"12345"`.

Header

```
// forwards to <boost/spirit/home/qi/directive/lexeme.hpp>
#include <boost/spirit/include/qi_lexeme.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lexeme // alias: boost::spirit::qi::lexeme`

Model of

`UnaryParser`

Notation

`a` A `Parser`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`lexeme[a]`	Turns off white space skipping for the subject parser, `a` (and all its children).

Attributes

See Compound Attribute Notation.

Expression	Attribute
`lexeme[a]`	`a: A --> lexeme[a]: A` `a: Unused --> lexeme[a]: Unused`

Complexity

The complexity is defined by the complexity of the subject parser, `a`

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::lexeme;
using boost::spirit::qi::lit;
using boost::spirit::ascii::digit;
```

Simple usage of `lexeme[]`:

The use of lexeme here will prevent skipping in between the digits and the sign making inputs such as `"1 2 345"` erroneous.

```
test_phrase_parser("12345", lexeme[ -(lit('+') | '-') >> +digit ]);
```

Inhibiting Case Sensitivity (`no_case[]`)

Description

The `no_case[]` directive does not consume any input. The actual matching is done by its subject parser. It's purpose is to force matching of the subject parser (and all its children) to be case insensitive.

Header

```
// forwards to <boost/spirit/home/qi/directive/no_case.hpp>
#include <boost/spirit/include/qi_no_case.hpp>
```

Also, see Include Structure.

Namespace

Name
`ns::no_case`

In the table above, `ns` represents a Character Encoding Namespace.

Model of

The model of `no_case` is the model of its subject parser.

Notation

`a` A `Parser`.

`ns` A Character Encoding Namespace.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in the subject's concept.

Expression	Semantics
`ns::no_case[a]`	Force matching of the subject parser, `a` (and all its children) to be case insensitive

Attributes

See Compound Attribute Notation.

Expression	Attribute
`ns::no_case[a]`	`a: A --> ns::no_case[a]: A` `a: Unused --> ns::no_case[a]: Unused`

Complexity

The complexity is defined by the complexity of the subject parser, `a`

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::no_case;
using boost::spirit::ascii::char_;
using boost::spirit::ascii::alnum;
using boost::spirit::qi::symbols;
```

Simple usage of `no_case[]`:

```
test_parser("X", no_case[char_('x')]);
test_parser("6", no_case[alnum]);
```

A more sophisticated use case of `no_case[]` in conjunction with a symbol table (see `symbols<Ch, T>` for more details):

```
symbols<char, int> sym;

sym.add
    ("apple", 1)    // symbol strings are added in lowercase...
    ("banana", 2)
    ("orange", 3)
;

int i;
// ...because sym is used for case-insensitive parsing
test_parser_attr("Apple", no_case[ sym ], i);
std::cout << i << std::endl;
test_parser_attr("ORANGE", no_case[ sym ], i);
std::cout << i << std::endl;
```

Ignoring Attribute (`omit[]`)

Description

The `omit[]` ignores the attribute of its subject parser replacing it with `unused`.

Header

```
// forwards to <boost/spirit/home/qi/directive/omit.hpp>
#include <boost/spirit/include/qi_omit.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::omit // alias: boost::spirit::qi::omit`

Model of

`UnaryParser`

Notation

a A `Parser`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`omit[a]`	Ignore the attribute of the subject parser, a

Attributes

Expression	Attribute
`omit[a]`	`unused_type`

Complexity

The complexity is defined by the complexity of the subject parser, a

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::omit;
using boost::spirit::qi::int_;
using boost::spirit::ascii::char_;
```

This parser ignores the first two characters and extracts the succeeding `int`:

```
int i;
test_parser_attr("xx345", omit[char_ >> char_] >> int_, i);
std::cout << i << std::endl; // should print 345
```

Transduction Parsing (`raw[]`)

Description

The `raw[]` disregards the attribute of its subject parser, instead exposing the half-open range `[first, last)` pointing to the matched characters from the input stream. The `raw[]` directive brings back the classic Spirit transduction (un-attributed) behavior for a subject parser.

Header

```
// forwards to <boost/spirit/home/qi/directive/raw.hpp>
#include <boost/spirit/include/qi_raw.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::raw // alias: boost::spirit::qi::raw`

Model of

`UnaryParser`

Notation

`a` A `Parser`.

`Iter` A `ForwardIterator` type.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`raw[a]`	Disregard the attribute of the subject parser, `a`. Expose instead the half-open range `[first, last)` pointing to the matched characters from the input stream.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`raw[a]`	`a: A --> raw[a]: boost::iterator_range<Iter>` `a: Unused --> raw[a]: Unused`

Note

See `boost::iterator_range`.

Complexity

The complexity is defined by the complexity of the subject parser, `a`

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::raw;
using boost::spirit::ascii::alpha;
using boost::spirit::ascii::alnum;
```

This parser matches and extracts C++ identifiers:

```
std::string id;
test_parser_attr("James007", raw[(alpha | '_') >> *(alnum | '_')], id);
std::cout << id << std::endl; // should print James007
```

Repetition (`repeat[]`)

Description

The `repeat[]` provides a more powerful and flexible mechanism for repeating a parser. There are grammars that are impractical and cumbersome, if not impossible, for the basic EBNF iteration syntax (Kleene and the Plus) to specify. Examples:

- A file name may have a maximum of 255 characters only.
- A specific bitmap file format has exactly 4096 RGB color information.
- A 256 bit binary string (1..256 1s or 0s).

Header

```
// forwards to <boost/spirit/home/qi/directive/repeat.hpp>
#include <boost/spirit/include/qi_repeat.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::repeat // alias: boost::spirit::qi::repeat`
`boost::spirit::inf // alias: boost::spirit::qi::inf`

Model of

`UnaryParser`

Notation

`a`	A `Parser`.
`n`, `min`, `max`	An `int` anything that can be converted to an `int`, or a Lazy Argument that evaluates to anything that can be converted to an `int`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`repeat[a]`	Repeat `a` zero or more times. Same as Kleene.
`repeat(n)[a]`	Repeat `a` exactly `n` times.
`repeat(min, max)[a]`	Repeat `a` at least `min` times and at most `max` times.
`repeat(min, inf)[a]`	Repeat `a` at least `min` or more (continuing until `a` fails or the input is consumed).

Attributes

See Compound Attribute Notation.

Expression	Attribute
`repeat[a]`	`a: A --> repeat[a]: vector<A>` `a: Unused --> repeat[a]: Unused`
`repeat(n)[a]`	`a: A --> repeat(n)[a]: vector<A>` `a: Unused --> repeat(n)[a]: Unused`
`repeat(min, max)[a]`	`a: A --> repeat(min, max)[a]: vector<A>` `a: Unused --> repeat(min, max)[a]: Unused`
`repeat(min, inf)[a]`	`a: A --> repeat(min, inf)[a]: vector<A>` `a: Unused --> repeat(min, inf)[a]: Unused`

Complexity

The overall complexity is defined by the complexity of its subject parser. The complexity of `repeat` itself is O(N), where N is the number of repetitions to execute.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Using the repeat directive, we can now write our examples above.

Some using declarations:

```
using boost::spirit::qi::repeat;
using boost::spirit::qi::lit;
using boost::spirit::qi::uint_parser;
using boost::spirit::qi::_1;
using boost::spirit::ascii::char_;
namespace phx = boost::phoenix;
```

A parser for a file name with a maximum of 255 characters:

```
test_parser("batman.jpeg", repeat(1, 255)[char_("a-zA-Z_./")]);
```

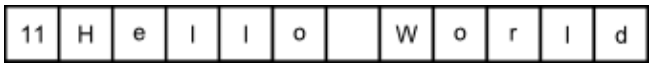
A parser for a specific bitmap file format which has exactly 4096 RGB color information. (for the purpose of this example, we will be testing only 3 RGB color information.)

```
uint_parser<unsigned, 16, 6, 6> rgb;
std::vector<unsigned> colors;
test_parser_attr("ffffff0000003f3f3f", repeat(3)[rgb], colors);
std::cout
    << std::hex
    << colors[0] << ','
    << colors[1] << ','
    << colors[2] << std::endl;
```

A 256 bit binary string (1..256 1s or 0s). (For the purpose of this example, we will be testing only 16 bits.)

```
test_parser("1011101011110010", repeat(16)[lit('1') | '0']);
```

The Loop parsers can be dynamic. Consider the parsing of a binary file of Pascal-style length prefixed string, where the first byte determines the length of the incoming string. Here's a sample input:



This trivial example cannot be practically defined in traditional EBNF. Although some EBNF variants allow more powerful repetition constructs other than the Kleene Star, we are still limited to parsing fixed strings. The nature of EBNF forces the repetition factor to be a constant. On the other hand, Spirit allows the repetition factor to be variable at run time. We could write a grammar that accepts the input string above. Example using phoenix:

```
std::string str;
int n;
test_parser_attr("\x0bHello World",
    char_[phx::ref(n) = _1] >> repeat(phx::ref(n))[char_], str);
std::cout << n << ',' << str << std::endl;  // will print "11,Hello World"
```

Re-Establish Skipping (`skip[]`)

Description

The `skip` directive is the inverse of `lexeme`. While the `lexeme` directive turns off white space skipping, the `skip` directive turns it on again. This is simply done by wrapping the parts inside the `skip` directive:

```
skip[a]
```

It is also possible to supply a skip parser to the `skip` directive:

```
skip(p)[a] // Use `p` as a skipper for parsing `a`
```

This makes it possible to:

- Perform localized phrase level parsing while doing character level parsing.
- Replace the current skipper anywhere with an entirely different skipper while doing phrase level parsing.

Header

```
// forwards to <boost/spirit/home/qi/directive/skip.hpp>
#include <boost/spirit/include/qi_skip.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::skip // alias: boost::spirit::qi::skip`

Model of

`UnaryParser`

Notation

`a` A `Parser`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`skip[a]`	Re-establish the skipper that got inhibited by lexeme
`skip(p)[a]`	Use `p` as a skipper for parsing `a`

Attributes

See Compound Attribute Notation.

Expression	Attribute
`skip[a]`	`a: A --> skip[a]: A` `a: Unused --> lexeme[a]: Unused`
`skip(p)[a]`	`a: A --> skip(p)[a]: A` `a: Unused --> lexeme[a]: Unused`

Complexity

The complexity is defined by the complexity of the subject parser, `a`

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::skip;
using boost::spirit::qi::int_;
using boost::spirit::ascii::space;
```

Simple usage of `skip[]`:

Explicitly specify a skip parser. This parser parses comma delimited numbers, ignoring spaces.

```
test_parser("1, 2, 3, 4, 5", skip(space)[int_ >> *(',' >> int_)]);
```

Nonterminal

Module Headers

```
// forwards to <boost/spirit/home/qi/nonterminal.hpp>
#include <boost/spirit/include/qi_nonterminal.hpp>
```

Also, see Include Structure.

Rule

Description

The rule is a polymorphic parser that acts as a named placeholder capturing the behavior of a Parsing Expression Grammar expression assigned to it. Naming a Parsing Expression Grammar expression allows it to be referenced later and makes it possible for the rule to call itself. This is one of the most important mechanisms and the reason behind the word "recursive" in recursive descent parsing.

Header

```
// forwards to <boost/spirit/home/qi/nonterminal/rule.hpp>
#include <boost/spirit/include/qi_rule.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::qi::rule`

Synopsis

```
template <typename Iterator, typename A1, typename A2, typename A3>
struct rule;
```

Template parameters

Parameter	Description	Default
`Iterator`	The underlying iterator type that the rule is expected to work on.	none
`A1`, `A2`, `A3`	Either `Signature`, `Skipper` or `Locals` in any order. See table below.	See table below.

Here is more information about the template parameters:

Parameter	Description	Default
`Signature`	Specifies the rule's synthesized (return value) and inherited attributes (arguments). More on this here: `Nonterminal`.	`unused_type`. When `Signature` defaults to `unused_type`, the effect is the same as specifying a signature of `void()` which is also equivalent to `unused_type()`
`Skipper`	Specifies the rule's skipper parser. Specify this if you want the rule to skip white spaces.	`unused_type`
`Locals`	Specifies the rule's local variables. See `Nonterminal`.	`unused_type`

Model of

`Nonterminal`

Notation

`r, r2`	Rules
`p`	A parser expression
`Iterator`	The underlying iterator type that the rule is expected to work on.
`A1, A2, A3`	Either `Signature`, `Skipper` or `Locals` in any order.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `Nonterminal`.

Expression	Description
`rule<Iterator, A1, A2, A3> r(name);`	Rule declaration. `Iterator` is required. `A1, A2, A3` are optional and can be specified in any order. `name` is an optional string that gives the rule its name, useful for debugging and error handling.
`rule<Iterator, A1, A2, A3> r(r2);`	Copy construct rule `r` from rule `r2`.
`r = r2;`	Assign rule `r2` to `r`.
`r.alias()`	return an alias of `r`. The alias is a parser that holds a reference to `r`.
`r.copy()`	Get a copy of `r`.
`r = p;`	Rule definition. This is equivalent to `r %= p` (see below) if there are no semantic actions attached anywhere in `p`.
`r %= p;`	Auto-rule definition. The attribute of `p` should be compatible with the synthesized attribute of `r`. When `p` is successful, its attribute is automatically propagated to `r`'s synthesized attribute.

Attributes

The parser attribute of the rule is `T`, its synthesized attribute. See `Attribute`

Complexity

The complexity is defined by the complexity of the RHS parser, `p`

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

[reference_rule]

Grammar

Description

The grammar encapsulates a set of rules (as well as primitive parsers (`PrimitiveParser`) and sub-grammars). The grammar is the main mechanism for modularization and composition. Grammars can be composed to form more complex grammars.

Header

```
// forwards to <boost/spirit/home/qi/nonterminal/grammar.hpp>
#include <boost/spirit/include/qi_grammar.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::qi::grammar`

Synopsis

```
template <typename Iterator, typename A1, typename A2, typename A3>
struct grammar;
```

Template parameters

Parameter	Description	Default
`Iterator`	The underlying iterator type that the rule is expected to work on.	none
`A1`, `A2`, `A3`	Either `Signature`, `Skipper` or `Locals` in any order. See table below.	See table below.

Here is more information about the template parameters:

Parameter	Description	Default
`Signature`	Specifies the grammar's synthesized (return value) and inherited attributes (arguments). More on this here: `Nonterminal`.	`unused_type`. When `Signature` defaults to `unused_type`, the effect is the same as specifying a signature of `void()` which is also equivalent to `unused_type()`
`Skipper`	Specifies the grammar's skipper parser. Specify this if you want the grammar to skip white spaces.	`unused_type`
`Locals`	Specifies the grammar's local variables. See `Nonterminal`.	`unused_type`

Model of

`Nonterminal`

Notation

`g` A grammar

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `Nonterminal`.

Expression	Semantics

`template <typename Iterator>`
`struct my_grammar : grammar<Iterator, A1, A2, A3>`
`{`
`  my_grammar() : my_grammar::base_type(start, name)`
`  {`
`  // Rule definitions`
`  start = /* ... */;`
`  }`
`  rule<Iterator, A1, A2, A3> start;`
`  // more rule declarations...`
`};`
	Grammar definition. `name` is an optional string that gives the grammar its name, useful for debugging and error handling.

Note

The template parameters of a grammar and its start rule (the rule passed to the grammar's base class constructor) must match, otherwise you will see compilation errors.

Attributes

The parser attribute of the grammar is `T`, its synthesized attribute. See `Attribute`

Complexity

The complexity is defined by the complexity of the its definition.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::space_type;
using boost::spirit::int_;
using boost::spirit::qi::grammar;
using boost::spirit::qi::rule;
```

Basic grammar usage:

```
struct num_list : grammar<char const*, space_type>
{
    num_list() : base_type(start)
    {
        using boost::spirit::int_;
        num = int_;
        start = num >> *(',' >> num);
    }

    rule<char const*, space_type> start, num;
};
```

How to use the example grammar:

```
num_list nlist;
test_phrase_parser("123, 456, 789", nlist);
```

Numeric

The library includes a couple of predefined objects for parsing signed and unsigned integers and real numbers. These parsers are fully parametric. Most of the important aspects of numeric parsing can be finely adjusted to suit. This includes the radix base, the minimum and maximum number of allowable digits, the exponent, the fraction etc. Policies control the real number parsers' behavior. There are some predefined policies covering the most common real number formats but the user can supply her own when needed.

The numeric parsers are fine tuned (employing loop unrolling and extensive template metaprogramming) with exceptional performance that rivals the low level C functions such as `atof`, `strtod`, `atol`, `strtol`. Benchmarks reveal up to 4X speed over the C counterparts. This goes to show that you can write extremely tight generic C++ code that rivals, if not surpasses C.

Module Header

```
// forwards to <boost/spirit/home/qi/numeric.hpp>
#include <boost/spirit/include/qi_numeric.hpp>
```

Also, see Include Structure.

Unsigned Integers (`uint_`, etc.)

Description

The `uint_parser` class is the simplest among the members of the numerics package. The `uint_parser` can parse unsigned integers of arbitrary length and size. The `uint_parser` parser can be used to parse ordinary primitive C/C++ integers or even user defined scalars such as bigints (unlimited precision integers) as long as the type follows certain expression requirements (documented below). The `uint_parser` is a template class. Template parameters fine tune its behavior.

Header

```
// forwards to <boost/spirit/home/qi/numeric/uint.hpp>
#include <boost/spirit/include/qi_uint.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::bin // alias: boost::spirit::qi::bin`
`boost::spirit::oct // alias: boost::spirit::qi::oct`
`boost::spirit::hex // alias: boost::spirit::qi::hex`
`boost::spirit::ushort_ // alias: boost::spirit::qi::ushort_`
`boost::spirit::ulong_ // alias: boost::spirit::qi::ulong_`
`boost::spirit::uint_ // alias: boost::spirit::qi::uint_`
`boost::spirit::ulong_long // alias: boost::spirit::qi::ulong_long`

Important

`ulong_long` is only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `unsigned long long` (64 bit) unsigned integer types).

Synopsis

```
template <
    typename T
  , unsigned Radix
  , unsigned MinDigits
  , int MaxDigits>
struct uint_parser;
```

Template parameters

Parameter	Description	Default
`T`	The numeric base type of the numeric parser.	none
`Radix`	The radix base. This can be either 2: binary, 8: octal, 10: decimal and 16: hexadecimal.	10
`MinDigits`	The minimum number of digits allowable.	1
`MaxDigits`	The maximum number of digits allowable. If this is -1, then the maximum limit becomes unbounded.	-1

Model of

`PrimitiveParser`

Notation

`NP` An instance of `uint_parser` (type).

`n` An object of `T`, the numeric base type.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`NP()`	Instantiate and (default) construct a `uint_parser`
`bin`	Create a `uint_parser<unsigned, 2, 1, -1>`
`oct`	Create a `uint_parser<unsigned, 8, 1, -1>`
`hex`	Create a `uint_parser<unsigned, 16, 1, -1>`
`ushort_`	Create a `uint_parser<unsigned short, 10, 1, -1>`
`ulong_`	Create a `uint_parser<unsigned long, 10, 1, -1>`
`uint_`	Create a `uint_parser<unsigned int, 10, 1, -1>`
`ulong_long`	Create a `uint_parser<unsigned long long, 10, 1, -1>`

Attributes

`T`, The numeric base type of the numeric parser.

Complexity

O(N), where N is the number of digits being parsed.

Minimum Expression Requirements for `T`

For the numeric base type, `T`, the expression requirements below must be valid:

Expression	Semantics
`T()`	Default construct.
`T(0)`	Construct from an `int`.
`n + n`	Addition.
`n * n`	Multiplication.
`std::numeric_limits<T>::is_bounded`	`true` or `false` if `T` bounded.
`std::numeric_limits<T>::digits`	Maximum Digits for `T`, radix digits. Required only if `T` is bounded.
`std::numeric_limits<T>::digits10`	Maximum Digits for `T`, base 10. Required only if `T` is bounded.
`std::numeric_limits<T>::max()`	Maximum value for `T`. Required only if `T` is bounded.
`std::numeric_limits<T>::min()`	Minimum value for `T`. Required only if `T` is bounded.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::uint_;
using boost::spirit::qi::uint_parser;
```

Basic unsigned integers:

```
test_parser("12345", uint_);
```

Thousand separated number parser:

```
uint_parser<unsigned, 10, 1, 3> uint3_p;        //  1..3 digits
uint_parser<unsigned, 10, 3, 3> uint3_3_p;      //  exactly 3 digits
test_parser("12,345,678", uint3_p >> *(',' >> uint3_3_p));
```

Signed Integers (`int_`, etc.)

Description

The `int_parser` can parse signed integers of arbitrary length and size. This is almost the same as the `uint_parser`. The only difference is the additional task of parsing the `'+'` or `'-'` sign preceding the number. The class interface is the same as that of the `uint_parser`.

The `int_parser` parser can be used to parse ordinary primitive C/C++ integers or even user defined scalars such as bigints (unlimited precision integers) as long as the type follows certain expression requirements (documented below).

Header

```
// forwards to <boost/spirit/home/qi/numeric/int.hpp>
#include <boost/spirit/include/qi_int.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::short_ // alias: boost::spirit::qi::short_`
`boost::spirit::int_ // alias: boost::spirit::qi::int_`
`boost::spirit::long_ // alias: boost::spirit::qi::long_`
`boost::spirit::long_long // alias: boost::spirit::qi::long_long`

Important

`long_long` is only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `signed long long` (64 bit) unsigned integer types).

Synopsis

```
template <
    typename T
  , unsigned Radix
  , unsigned MinDigits
  , int MaxDigits>
struct int_parser;
```

Template parameters

Parameter	Description	Default
`T`	The numeric base type of the numeric parser.	none
`Radix`	The radix base. This can be either 2: binary, 8: octal, 10: decimal and 16: hexadecimal.	10
`MinDigits`	The minimum number of digits allowable.	1
`MaxDigits`	The maximum number of digits allowable. If this is -1, then the maximum limit becomes unbounded.	-1

Model of

`PrimitiveParser`

Notation

`NP` An instance of `int_parser` (type).

`n` An object of `T`, the numeric base type.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`NP()`	Instantiate and (default) construct an `int_parser`
`short_`	Create an `int_parser<short, 10, 1, -1>`
`long_`	Create an `int_parser<long, 10, 1, -1>`
`int_`	Create an `int_parser<int, 10, 1, -1>`
`long_long`	Create an `int_parser<long long, 10, 1, -1>`

Attributes

T, The numeric base type of the numeric parser.

Complexity

O(N), where N is the number of digits being parsed plus the sign.

Minimum Expression Requirements for T

For the numeric base type, T, the expression requirements below must be valid:

Expression	Semantics
`T()`	Default construct.
`T(0)`	Construct from an `int`.
`n + n`	Addition.
`n - n`	Subtraction.
`n * n`	Multiplication.
`std::numeric_limits<T>::is_bounded`	`true` or `false` if `T` bounded.
`std::numeric_limits<T>::digits`	Maximum Digits for `T`, radix digits. Required only if `T` is bounded.
`std::numeric_limits<T>::digits10`	Maximum Digits for `T`, base 10. Required only if `T` is bounded.
`std::numeric_limits<T>::max()`	Maximum value for `T`. Required only if `T` is bounded.
`std::numeric_limits<T>::min()`	Minimum value for `T`. Required only if `T` is bounded.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::int_;
```

Basic signed integers:

```
test_parser("+12345", int_);
test_parser("-12345", int_);
```

Real Numbers (`float_`, `double_`, etc.)

Description

The `real_parser` can parse real numbers of arbitrary length and size limited by its template parameter, `T`. The numeric base type `T` can be a user defined numeric type such as fixed_point (fixed point reals) and bignum (unlimited precision numbers) as long as the type follows certain expression requirements (documented below).

Header

```
// forwards to <boost/spirit/home/qi/numeric/real.hpp>
#include <boost/spirit/include/qi_real.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::float_ // alias: boost::spirit::qi::float_`
`boost::spirit::double_ // alias: boost::spirit::qi::double_`
`boost::spirit::long_double // alias: boost::spirit::qi::long_double`

Synopsis

```
template <typename T, typename RealPolicies>
struct real_parser;
```

Template parameters

Parameter	Description	Default
`T`	The numeric base type of the numeric parser.	none
`RealPolicies`	Policies control the parser's behavior.	`real_policies<T>`

Model of

`PrimitiveParser`

Notation

`NP`	An instance of `real_parser` (type).
`RP`	A `RealPolicies` (type).
`n`	An object of `T`, the numeric base type.
`exp`	A `int` exponent.

`b`	A `bool` flag.
`f`, `l`	`ForwardIterator`. first/last iterator pair.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`NP()`	Instantiate and (default) construct an `real_parser`
`float_`	Create an `real_parser<float, real_policies<T> >`
`double_`	Create an `real_parser<double, real_policies<T> >`
`long_double`	Create an `real_parser<long double, real_policies<T> >`

Attributes

`T`, The numeric base type of the numeric parser.

Complexity

O(N), where N is the number of characters (including the digits, exponent, sign, etc.) being parsed.

Minimum Expression Requirements for `T`

The numeric base type, `T`, the minimum expression requirements listed below must be valid. Take note that additional requirements may be imposed by custom policies.

Expression	Semantics
`T()`	Default construct.
`T(0)`	Construct from an `int`.
`n + n`	Addition.
`n - n`	Subtraction.
`n * n`	Multiplication.
`std::numeric_limits<T>::is_bounded`	`true` or `false` if `T` bounded.
`std::numeric_limits<T>::digits`	Maximum Digits for `T`, radix digits. Required only if `T` is bounded.
`std::numeric_limits<T>::digits10`	Maximum Digits for `T`, base 10. Required only if `T` is bounded.
`std::numeric_limits<T>::max()`	Maximum value for `T`. Required only if `T` is bounded.
`std::numeric_limits<T>::min()`	Minimum value for `T`. Required only if `T` is bounded.
`boost::spirit::traits::scale(exp, n)`	Multiply `n` by `10^exp`. Default implementation is provided for `float`, `double` and `long double`.
`boost::spirit::traits::negate(b, n)`	Negate `n` if `b` is `true`. Default implementation is provided for `float`, `double` and `long double`.
`boost::spirit::traits::is_equal_to_one(n)`	Return `true` if `n` is equal to `1.0`. Default implementation is provided for `float`, `double` and `long double`.

Note

The additional spirit real number traits above are provided to allow custom implementations to implement efficient real number parsers. For example, for certain custom real numbers, scaling to a base 10 exponent is a very cheap operation.

`RealPolicies`

The `RealPolicies` template parameter is a class that groups all the policies that control the parser's behavior. Policies control the real number parsers' behavior.

The default is `real_policies<T>`. The default is provided to take care of the most common case (there are many ways to represent, and hence parse, real numbers). In most cases, the default policies are sufficient and can be used straight out of the box. They are designed to parse C/C++ style floating point numbers of the form `nnn.fff.Eeee` where `nnn` is the whole number part, `fff` is the fractional part, `E` is `'e'` or `'E'` and `eee` is the exponent optionally preceded by `'-'` or `'+'` with the additional detection of NaN and Inf as mandated by the C99 Standard and proposed for inclusion into the C++0x Standard: nan, nan(...), inf and infinity (the matching is case-insensitive). This corresponds to the following grammar:

```
sign
    =   lit('+') | '-'
    ;

nan
    =   -lit("1.0#") >> no_case["nan"]
        >> -('(' >> *(char_ - ')') >> ')')
    ;

inf
    =   no_case[lit("inf") >> -lit("inity")]
    ;

floating_literal
    =   -sign >>
        (       nan
            |   inf
            |   fractional_constant >> !exponent_part
            |  +digit >> exponent_part
        )
    ;

fractional_constant
    =  *digit >> '.' >> +digit
    |  +digit >> -lit('.')
    ;

exponent_part
    =   (lit('e') | 'E') >> -sign >> +digit
    ;
```

There are four `RealPolicies` pre-defined for immediate use:

Table 4. Predefined Policies

Policies	Description
`ureal_policies<double> >`	Without sign.
`real_policies<double> >`	With sign.
`strict_ureal_policies<double> >`	Without sign, dot required.
`strict_real_policies<double> >`	With sign, dot required.

Note

Integers are considered a subset of real numbers, so for instance, `double_` recognizes integer numbers (without a dot) just as well. To avoid this ambiguity, `strict_ureal_policies` and `strict_real_policies` require a dot to be present for a number to be considered a successful match.

`RealPolicies` Expression Requirements

For models of `RealPolicies` the following expressions must be valid:

Expression	Semantics
`RP::allow_leading_dot`	Allow leading dot.
`RP::allow_trailing_dot`	Allow trailing dot.
`RP::expect_dot`	Require a dot.
`RP::parse_sign(f, l)`	Parse the prefix sign (e.g. '-'). Return `true` if successful, otherwise `false`.
`RP::parse_n(f, l, n)`	Parse the integer at the left of the decimal point. Return `true` if successful, otherwise `false`. If successful, place the result into `n`.
`RP::parse_dot(f, l)`	Parse the decimal point. Return `true` if successful, otherwise `false`.
`RP::parse_frac_n(f, l, n)`	Parse the fraction after the decimal point. Return `true` if successful, otherwise `false`. If successful, place the result into `n`.
`RP::parse_exp(f, l)`	Parse the exponent prefix (e.g. 'e'). Return `true` if successful, otherwise `false`.
`RP::parse_exp_n(f, l, n)`	Parse the actual exponent. Return `true` if successful, otherwise `false`. If successful, place the result into `n`.
`RP::parse_nan(f, l, n)`	Parse a NaN. Return `true` if successful, otherwise `false`. If successful, place the result into `n`.
`RP::parse_inf(f, l, n)`	Parse an Inf. Return `true` if successful, otherwise `false`. If successful, place the result into `n`.

The `parse_nan` and `parse_inf` functions get called whenever:

> a number to parse does not start with a digit (after having successfully parsed an optional sign)

or

> after a real number of the value 1 (having no exponential part and a fractional part value of 0) has been parsed.

The first call recognizes representations of NaN or Inf starting with a non-digit character (such as NaN, Inf, QNaN etc.). The second call recognizes representation formats starting with a `1.0` (such as `"1.0#NAN"` or `"1.0#INF"` etc.).

The functions should return true if a Nan or Inf has been found. In this case the attribute `n` should be set to the matched value (NaN or Inf). The optional sign will be automatically applied afterwards.

`RealPolicies` Specializations

The easiest way to implement a proper real parsing policy is to derive a new type from the the type `real_policies` while overriding the aspects of the parsing which need to be changed. For example, here's the implementation of the pre-defined `strict_real_policies`:

```
template <typename T>
struct strict_real_policies : real_policies<T>
{
    static bool const expect_dot = true;
};
```

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::double_;
using boost::spirit::qi::real_parser;
```

Basic real number parsing:

```
test_parser("+12345e6", double_);
```

A custom real number policy:

```
///////////////////////////////////////////////////////////////////////////
//  These policies can be used to parse thousand separated
//  numbers with at most 2 decimal digits after the decimal
//  point. e.g. 123,456,789.01
///////////////////////////////////////////////////////////////////////////
template <typename T>
struct ts_real_policies : boost::spirit::qi::ureal_policies<T>
{
    //  2 decimal places Max
    template <typename Iterator, typename Attribute>
    static bool
    parse_frac_n(Iterator& first, Iterator const& last, Attribute& attr)
    {
        return boost::spirit::qi::
            extract_uint<T, 10, 1, 2, true>::call(first, last, attr);
    }

    //  No exponent
    template <typename Iterator>
    static bool
    parse_exp(Iterator&, Iterator const&)
    {
        return false;
    }

    //  No exponent
    template <typename Iterator, typename Attribute>
    static bool
    parse_exp_n(Iterator&, Iterator const&, Attribute&)
    {
        return false;
    }

    //  Thousands separated numbers
    template <typename Iterator, typename Attribute>
    static bool
    parse_n(Iterator& first, Iterator const& last, Attribute& attr)
    {
        using boost::spirit::qi::uint_parser;
        namespace qi = boost::spirit::qi;

        uint_parser<unsigned, 10, 1, 3> uint3;
        uint_parser<unsigned, 10, 3, 3> uint3_3;

        T result = 0;
        if (parse(first, last, uint3, result))
        {
            bool hit = false;
            T n;
            Iterator save = first;

            while (qi::parse(first, last, ',') && qi::parse(first, last, uint3_3, n))
            {
                result = result * 1000 + n;
                save = first;
                hit = true;
            }

            first = save;
            if (hit)
```

```
                attr = result;
            return hit;
        }
        return false;
    }
};
```

And its use:

```
real_parser<double, ts_real_policies<double> > ts_real;
test_parser("123,456,789.01", ts_real);
```

Boolean Parser (`bool_`)

Description

The `bool_parser` can parse booleans of arbitrary type, `B`. The boolean base type `T` can be a user defined boolean type as long as the type follows certain expression requirements (documented below).

Header

```
// forwards to <boost/spirit/home/qi/numeric/bool.hpp>
#include <boost/spirit/include/qi_bool.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::bool_ // alias: boost::spirit::qi::bool_`
`boost::spirit::true_ // alias: boost::spirit::qi::true_`
`boost::spirit::false_ // alias: boost::spirit::qi::false_`

Synopsis

```
template <typename T, typename BooleanPolicies>
struct bool_parser;
```

Template parameters

Parameter	Description	Default
`B`	The boolean type of the boolean parser.	`bool`
`BooleanPolicies`	Policies control the parser's behavior.	`bool_policies<B>`

Model of

`PrimitiveParser`

Notation

`BP`	An instance of `bool_parser` (type).
`BP`	A boolean `Policies` (type).
`b`	An object of `B`, the numeric base type.
`f`, `l`	`ForwardIterator`. first/last iterator pair.
`attr`	An attribute value.
`Context`	The type of the parse context of the current invocation of the `bool_` parser.
`ctx`	An instance of the parse context, `Context`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`BP()`	Instantiate and (default) construct a `bool_parser`
`bool_`	Create a `bool_parser<bool, bool_policies<bool> >`
`true_`	Create a `bool_parser<bool, bool_policies<bool> >` which is succeeding only after matching `"true"`.
`false_`	Create a `bool_parser<bool, bool_policies<bool> >` which is succeeding only after matching `"false"`.

Note

All boolean parsers properly respect the `no_case[]` directive.

Attributes

`B`, The boolean type of the booelan parser.

Complexity

O(N), where N is the number of characters being parsed.

Minimum Expression Requirements for `B`

The boolean type, `B`, the minimum expression requirements listed below must be valid. Take note that additional requirements may be imposed by custom policies.

Expression	Semantics
`B(bool)`	Constructible from a `bool`.

Boolean `Policies`

The boolean `Policies` template parameter is a class that groups all the policies that control the parser's behavior. Policies control the boolean parsers' behavior.

The default is `bool_policies<bool>`. The default is provided to take care of the most common case (there are many ways to represent, and hence parse, boolean numbers). In most cases, the default policies are sufficient and can be used straight out of the box. They are designed to parse boolean value of the form `"true"` and `"false"`.

Boolean `Policies` Expression Requirements

For models of boolean `Policies` the following expressions must be valid:

Expression	Semantics
`BP::parse_true(f, l, attr, ctx)`	Parse a `true` value.
`BP::parse_false(f, l, attr, ctx)`	Parse a `false` value.

The functions should return true if the required representations of `true` or `false` have been found. In this case the attribute `n` should be set to the matched value (`true` or `false`).

Boolean `Policies` Specializations

The easiest way to implement a proper boolean parsing policy is to derive a new type from the the type `bool_policies` while overriding the aspects of the parsing which need to be changed. For example, here's the implementation of a boolean parsing policy interpreting the string `"eurt"` (i.e. "true" spelled backwards) as `false`:

```
struct backwards_bool_policies : qi::bool_policies<>
{
    // we want to interpret a 'true' spelled backwards as 'false'
    template <typename Iterator, typename Attribute, typename Context>
    static bool
    parse_false(Iterator& first, Iterator const& last, Attribute& attr, Context& ctx)
    {
        namespace qi = boost::spirit::qi;
        if (qi::detail::string_parse("eurt", first, last, qi::unused, qi::unused))
        {
            spirit::traits::assign_to(false, attr, ctx);    // result is false
            return true;
        }
        return false;
    }
};
```

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::bool_;
using boost::spirit::qi::bool_parser;
```

Basic real number parsing:

```
test_parser("true", bool_);
test_parser("false", bool_);
```

A custom real number policy:

```
///////////////////////////////////////////////////////////////////////////
//  These policies can be used to parse "eurt" (i.e. "true" spelled backwards)
//  as `false`
///////////////////////////////////////////////////////////////////////////
struct backwards_bool_policies : boost::spirit::qi::bool_policies<>
{
    // we want to interpret a 'true' spelled backwards as 'false'
    template <typename Iterator, typename Attribute>
    static bool
    parse_false(Iterator& first, Iterator const& last, Attribute& attr)
    {
        namespace qi = boost::spirit::qi;
        if (qi::detail::string_parse("eurt", first, last, qi::unused))
        {
            namespace traits = boost::spirit::traits;
            traits::assign_to(false, attr);    // result is false
            return true;
        }
        return false;
    }
};
```

And its use:

```
bool_parser<bool, backwards_bool_policies> backwards_bool;
test_parser("true", backwards_bool);
test_parser("eurt", backwards_bool);
```

Operator

Operators are used as a means for object composition and embedding. Simple parsers may be composed to form composites through operator overloading, crafted to approximate the syntax of Parsing Expression Grammar (PEG). An expression such as:

```
a | b
```

yields a new parser type which is a composite of its operands, `a` and `b`.

This module includes different parsers which get instantiated if one of the overloaded operators is used with more primitive parser constructs. It includes Alternative (`|`), And predicate (unary `&`), Difference (`-`), Expect (`>`), Kleene star (unary `*`), Lists (`%`), Not predicate (`!`), Optional (unary `-`), Permutation (`^`), Plus (unary `+`), Sequence (`>>`), and Sequential-Or (`||`).

Module Header

```
// forwards to <boost/spirit/home/qi/operator.hpp>
#include <boost/spirit/include/qi_operator.hpp>
```

Also, see Include Structure.

Alternative (`a | b`)

Description

The alternative operator, `a | b`, matches one of two or more operands (a, b, ... etc.):

```
a | b | ...
```

Alternative operands are tried one by one on a first-match-wins basis starting from the leftmost operand. After a successfully matched alternative is found, the parser concludes its search, essentially short-circuiting the search for other potentially viable candidates. This short-circuiting implicitly gives the highest priority to the leftmost alternative.

Short-circuiting is done in the same manner as C or C++'s logical expressions; e.g. `if (x < 3 || y < 2)` where, if `x < 3`, the `y < 2` test is not done at all. In addition to providing an implicit priority rule for alternatives which is necessary, given its non-deterministic nature, short-circuiting improves the execution time. If the order of your alternatives is logically irrelevant, strive to put the (expected) most common choice first for maximum efficiency.

Header

```
// forwards to <boost/spirit/home/qi/operator/alternative.hpp>
#include <boost/spirit/include/qi_alternative.hpp>
```

Also, see Include Structure.

Model of

`NaryParser`

Notation

a, b — A `Parser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `NaryParser`.

Expression	Semantics
`a | b`	Match a or b.

Attributes

See Compound Attribute Notation.

Expression	Attribute

`a | b`	`a: A, b: B --> (a | b): variant<A, B>`
	`a: A, b: Unused --> (a | b): optional<A>`
	`a: A, b: B, c: Unused --> (a | b | c): option↵al<variant<A, B> >`
	`a: Unused, b: B --> (a | b): optional<B>`
	`a: Unused, b: Unused --> (a | b): Unused`
	`a: A, b: A --> (a | b): A`

Complexity

The overall complexity of the alternative parser is defined by the sum of the complexities of its elements. The complexity of the alternative parser itself is O(N), where N is the number of alternatives.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::string;
using boost::spirit::qi::int_;
using boost::spirit::qi::_1;
using boost::variant;
```

Simple usage:

```
test_parser("Hello", string("Hello") | int_);
test_parser("123", string("Hello") | int_);
```

Extracting the attribute variant (using Boost.Variant):

```
variant<std::string, int> attr;
test_parser_attr("Hello", string("Hello") | int_, attr);
```

This should print `"Hello"`. Note: There are better ways to extract the value from the variant. See Boost.Variant visitation. This code is solely for demonstration.

```
if (boost::get<int>(&attr))
    std::cout << boost::get<int>(attr) << std::endl;
else
    std::cout << boost::get<std::string>(attr) << std::endl;
```

Extracting the attributes using Semantic Actions with Phoenix (this should print `123`):

```
test_parser("123", (string("Hello") | int_)[std::cout << _1 << std::endl]);
```

And Predicate (&a)

Description

Syntactic predicates assert a certain conditional syntax to be satisfied before evaluating another production. Similar to semantic predicates, `eps`, syntactic predicates do not consume any input. The *and predicate*, `&a`, is a positive syntactic predicate that returns a zero length match only if its predicate matches.

Header

```
// forwards to <boost/spirit/home/qi/operator/and_predicate.hpp>
#include <boost/spirit/include/qi_and_predicate.hpp>
```

Also, see Include Structure.

Model of

`UnaryParser`

Notation

`a` A `Parser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`&a`	If the predicate `a` matches, return a zero length match. Otherwise, fail.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`&a`	`unused_type`

Complexity

The complexity is defined by the complexity of the predicate, `a`

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::lit;
```

Basic look-ahead example: make sure that the last character is a semicolon, but don't consume it, just peek at the next character:

```
test_phrase_parser("Hello ;", lit("Hello") >> &lit(';'), false);
```

Difference (`a - b`)

Description

The difference operator, `a - b`, is a binary operator that matches the first (LHS) operand but not the second (RHS). [8]

Header

```
// forwards to <boost/spirit/home/qi/operator/difference.hpp>
#include <boost/spirit/include/qi_difference.hpp>
```

Also, see Include Structure.

[8] Unlike classic Spirit, with Spirit2, the expression will always fail if the RHS is a successful match regardless if the RHS matches less characters. For example, the rule `lit("policeman") - "police"` will always fail to match. Spirit2 does not count the matching chars while parsing and there is no reliable and fast way to check if the LHS matches more than the RHS.

Model of

`BinaryParser`

Notation

a, b A `Parser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `BinaryParser`.

Expression	Semantics
`a - b`	Parse a but not b.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`a - b`	`a: A, b: B --> (a - b): A` `a: Unused, b: B --> (a - b): Unused`

Complexity

The complexity of the difference parser is defined by the sum of the complexities of both operands.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::char_;
```

Parse a C/C++ style comment:

```
test_parser("/*A Comment*/", "/*" >> *(char_ - "*/") >> "*/");
```

Expectation (`a > b`)

Description

Like the Sequence, the expectation operator, `a > b`, parses two or more operands (a, b, ... etc.), in sequence:

```
a > b > ...
```

However, while the plain Sequence simply returns a no-match (returns `false`) when one of the elements fail, the expectation: `>` operator throws an `expectation_failure<Iter>` when the second or succeeding operands (all operands except the first) fail to match.

Header

```
// forwards to <boost/spirit/home/qi/operator/expect.hpp>
#include <boost/spirit/include/qi_expect.hpp>
```

Also, see Include Structure.

Model of

`NaryParser`

Notation

a, b	A `Parser`
`Iter`	A `ForwardIterator` type

Expectation Failure

When any operand, except the first, fail to match an `expectation_failure<Iter>` is thrown:

```
template <typename Iter>
struct expectation_failure : std::runtime_error
{
    Iter first;           // [first, last) iterator pointing
    Iter last;            // to the error position in the input.
    info what_;       // Information about the nature of the error.
};
```

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `NaryParser`.

Expression	Semantics
`a > b`	Match a followed by b. If a fails, no-match. If b fails, throw an `expectation_failure<Iter>`

Attributes

See Compound Attribute Notation.

Expression	Attribute

`a > b`	`a: A, b: B --> (a > b): tuple<A, B>`
	`a: A, b: Unused --> (a > b): A`
	`a: Unused, b: B --> (a > b): B`
	`a: Unused, b: Unused --> (a > b): Unused`
	
	`a: A, b: A --> (a > b): vector<A>`
	`a: vector<A>, b: A --> (a > b): vector<A>`
	`a: A, b: vector<A> --> (a > b): vector<A>`
	`a: vector<A>, b: vector<A> --> (a > b): vector<A>`

Complexity

The overall complexity of the expectation parser is defined by the sum of the complexities of its elements. The complexity of the expectation operator itself is O(N), where N is the number of elements in the sequence.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::char_;
using boost::spirit::qi::expectation_failure;
```

The code below uses an expectation operator to throw an `expectation_failure` with a deliberate parsing error when `"o"` is expected and `"i"` is what is found in the input. The `catch` block prints the information related to the error. Note: This is low level code that demonstrates the *bare-metal*. Typically, you use an Error Handler to deal with the error.

```
try
{
    test_parser("xi", char_('x') > char_('o')); // should throw an exception
}
catch (expectation_failure<char const*> const& x)
{
    std::cout << "expected: "; print_info(x.what_);
    std::cout << "got: \"" << std::string(x.first, x.last) << '"' << std::endl;
}
```

The code above will print:

```
expected: tag: literal-char, value: o
got: "i"
```

Kleene (*a)

Description

The kleene operator, `*a`, is a unary operator that matches its operand zero or more times.

Header

```
// forwards to <boost/spirit/home/qi/operator/kleene.hpp>
#include <boost/spirit/include/qi_kleene.hpp>
```

Also, see Include Structure.

Model of

UnaryParser

Notation

a A Parser

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in UnaryParser.

Expression	Semantics
*a	Match a zero or more times.

Attributes

See Compound Attribute Notation.

Expression	Attribute
*a	a: A --> *a: vector<A> a: Unused --> *a: Unused

Complexity

The overall complexity of the Kleene star is defined by the complexity of its subject, a, multiplied by the number of repetitions. The complexity of the Kleene star itself is O(N), where N is the number successful repetitions.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::int_;
```

Parse a comma separated list of numbers and put them in a vector:

```
std::vector<int> attr;
test_phrase_parser_attr(
    "111, 222, 333, 444, 555", int_ >> *(',' >> int_), attr);
std::cout
    << attr[0] << ',' << attr[1] << ',' << attr[2] << ','
    << attr[3] << ',' << attr[4]
    << std::endl;
```

List (`a % b`)

Description

The list operator, `a % b`, is a binary operator that matches a list of one or more repetitions of `a` separated by occurrences of `b`. This is equivalent to `a >> *(b >> a)`.

Header

```
// forwards to <boost/spirit/home/qi/operator/list.hpp>
#include <boost/spirit/include/qi_list.hpp>
```

Also, see Include Structure.

Model of

`BinaryParser`

Notation

a, b — A `Parser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `BinaryParser`.

Expression	Semantics
`a % b`	Match a list of one or more repetitions of `a` separated by occurrences of `b`. This is equivalent to `a >> *(b >> a)`.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`a % b`	`a: A, b: B --> (a % b): vector<A>` `a: Unused, b: B --> (a % b): Unused`

Complexity

The overall complexity of the List is defined by the complexity of its subject, `a`, multiplied by the number of repetitions. The complexity of the List itself is O(N), where N is the number successful repetitions.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::int_;
```

Parse a comma separated list of numbers and put them in a vector:

```
std::vector<int> attr;
test_phrase_parser_attr(
    "111, 222, 333, 444, 555", int_ % ',', attr);
std::cout
    << attr[0] << ',' << attr[1] << ',' << attr[2] << ','
    << attr[3] << ',' << attr[4]
    << std::endl;
```

Not Predicate (`!a`)

Description

Syntactic predicates assert a certain conditional syntax to be satisfied before evaluating another production. Similar to semantic predicates, `eps`, syntactic predicates do not consume any input. The *not predicate*, `!a`, is a negative syntactic predicate that returns a zero length match only if its predicate fails to match.

Header

```
// forwards to <boost/spirit/home/qi/operator/not_predicate.hpp>
#include <boost/spirit/include/qi_not_predicate.hpp>
```

Also, see Include Structure.

Model of

`UnaryParser`

Notation

a A `Parser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`!a`	If the predicate a matches, fail. Otherwise, return a zero length match.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`!a`	`unused_type`

Complexity

The complexity is defined by the complexity of the predicate, `a`

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::char_;
using boost::spirit::ascii::alpha;
using boost::spirit::qi::lit;
using boost::spirit::qi::symbols;
```

Here's an alternative to the `*(r - x) >> x` idiom using the not-predicate instead. This parses a list of characters terminated by a ';':

```
test_parser("abcdef;", *(!lit(';') >> char_) >> ';');
```

The following parser ensures that we match distinct keywords (stored in a symbol table). To do this, we make sure that the keyword does not follow an alpha or an underscore:

```
symbols<char, int> keywords;
keywords = "begin", "end", "for";

// This should fail:
test_parser("beginner", keywords >> !(alpha | '_'));

// This is ok:
test_parser("end ", keywords >> !(alpha | '_'), false);

// This is ok:
test_parser("for()", keywords >> !(alpha | '_'), false);
```

Optional (`-a`)

Description

The optional operator, `-a`, is a unary operator that matches its operand zero or one time.

Header

```
// forwards to <boost/spirit/home/qi/operator/optional.hpp>
#include <boost/spirit/include/qi_optional.hpp>
```

Also, see Include Structure.

Model of

`UnaryParser`

Notation

`a` A `Parser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`-a`	Match `a` zero or one time.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`-a`	`a: A --> -a: optional<A>` `a: Unused --> -a: Unused`

Complexity

The complexity is defined by the complexity of the operand, `a`

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::char_;
using boost::spirit::qi::lexeme;
using boost::spirit::qi::int_;
using boost::fusion::vector;
using boost::fusion::at_c;
using boost::optional;
```

Parse a person info with name (in quotes) optional age [9] and optional sex, all separated by comma.

[9] James Bond is shy about his age :-)

```
vector<std::string, optional<int>, optional<char> > attr;

test_phrase_parser_attr(
    "\"James Bond\", M"
  , lexeme['"' >> +(char_ - '"') >> '"']    // name
        >> -(',' >> int_)                   // optional age
        >> -(',' >> char_)                  // optional sex
  , attr);

// Should print: James Bond,M
std::cout << at_c<0>(attr);                 // print name
if (at_c<1>(attr))                          // print optional age
    std::cout << ',' << *at_c<1>(attr);
if (at_c<2>(attr))                          // print optional sex
    std::cout << ',' << *at_c<2>(attr);
std::cout << std::endl;
```

Permutation (`a ^ b`)

Description

The permutation operator, `a ^ b`, matches one or more operands (`a`, `b`, ... etc.) in any order:

```
a ^ b ^ ...
```

The operands are the elements in the permutation set. Each element in the permutation set may occur at most once, but not all elements of the given set need to be present. For example:

```
char_('a') ^ 'b' ^ 'c'
```

matches:

```
"a", "ab", "abc", "cba", "bca" ... etc.
```

Header

```
// forwards to <boost/spirit/home/qi/operator/permutation.hpp>
#include <boost/spirit/include/qi_permutation.hpp>
```

Also, see Include Structure.

Model of

`NaryParser`

Notation

a, b	A `Parser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `NaryParser`.

Expression	Semantics
`a ^ b`	Match `a` or `b` in any order. Each operand may match zero or one time as long as at least one operand matches.

Attributes

See Compound Attribute Notation.

Expression	Attribute

`a ^ b`	`a: A, b: B --> (a ^ b): tuple<optional<A>, optional<B> >`
	`a: A, b: Unused --> (a ^ b): optional<A>`
	`a: Unused, b: B --> (a ^ b): optional<B>`
	`a: Unused, b: Unused --> (a ^ b): Unused`

Complexity

The overall complexity of the permutation parser is defined by the sum of the complexities of its elements, s, multiplied by log s. The complexity of the permutation parser itself is O(N log N), where N is the number of elements.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::char_;
```

Parse a string containing DNA codes (ACTG)

```
test_parser("ACTGGCTAGACT", *(char_('A') ^ 'C' ^ 'T' ^ 'G'));
```

Plus (+a)

Description

The plus operator, +a, is a unary operator that matches its operand one or more times.

Header

```
// forwards to <boost/spirit/home/qi/operator/plus.hpp>
#include <boost/spirit/include/qi_plus.hpp>
```

Also, see Include Structure.

Model of

`UnaryParser`

Notation

`a` A `Parser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryParser`.

Expression	Semantics
`+a`	Match `a` one or more times.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`+a`	`a: A --> +a: vector<A>` `a: Unused --> +a: Unused`

Complexity

The overall complexity of the Plus is defined by the complexity of its subject, `a`, multiplied by the number of repetitions. The complexity of the Plus itself is O(N), where N is the number successful repetitions.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::alpha;
using boost::spirit::qi::lexeme;
```

Parse one or more strings containing one or more alphabetic characters and put them in a vector:

```
std::vector<std::string> attr;
test_phrase_parser_attr("yaba daba doo", +lexeme[+alpha], attr);
std::cout << attr[0] << ',' << attr[1] << ',' << attr[2] << std::endl;
```

Sequence (`a >> b`)

Description

The sequence operator, `a >> b`, parses two or more operands (`a`, `b`, ... etc.), in sequence:

```
a >> b >> ...
```

Header

```
// forwards to <boost/spirit/home/qi/operator/sequence.hpp>
#include <boost/spirit/include/qi_sequence.hpp>
```

Also, see Include Structure.

Model of

NaryParser

Notation

a, b — A Parser

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in NaryParser.

Expression	Semantics
a >> b	Match a followed by b.

Attributes

See Compound Attribute Notation.

Expression	Attribute
a >> b	a: A, b: B --> (a >> b): tuple<A, B> a: A, b: Unused --> (a >> b): A a: Unused, b: B --> (a >> b): B a: Unused, b: Unused --> (a >> b): Unused a: A, b: A --> (a >> b): vector<A> a: vector<A>, b: A --> (a >> b): vector<A> a: A, b: vector<A> --> (a >> b): vector<A> a: vector<A>, b: vector<A> --> (a >> b): vec↵ tor<A>

Complexity

The overall complexity of the sequence parser is defined by the sum of the complexities of its elements. The complexity of the sequence itself is O(N), where N is the number of elements in the sequence.

Example

Some using declarations:

```
using boost::spirit::ascii::char_;
using boost::spirit::qi::_1;
using boost::spirit::qi::_2;
namespace bf = boost::fusion;
```

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Simple usage:

```
test_parser("xy", char_ >> char_);
```

Extracting the attribute tuple (using Boost.Fusion):

```
bf::vector<char, char> attr;
test_parser_attr("xy", char_ >> char_, attr);
std::cout << bf::at_c<0>(attr) << ',' << bf::at_c<1>(attr) << std::endl;
```

Extracting the attribute vector (using STL):

```
std::vector<char> vec;
test_parser_attr("xy", char_ >> char_, vec);
std::cout << vec[0] << ',' << vec[1] << std::endl;
```

Extracting the attributes using Semantic Actions (using Phoenix):

```
test_parser("xy", (char_ >> char_)[std::cout << _1 << ',' << _2 << std::endl]);
```

Sequential Or (`a || b`)

Description

The sequential-or operator, `a || b`, matches `a` or `b` or `a` followed by `b`. That is, if both `a` and `b` match, it must be in sequence; this is equivalent to `a >> -b | b`:

```
a || b || ...
```

Header

```
// forwards to <boost/spirit/home/qi/operator/sequential_or.hpp>
#include <boost/spirit/include/qi_sequential_or.hpp>
```

Also, see Include Structure.

Model of

`NaryParser`

Notation

a, b	A `Parser`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `NaryParser`.

Expression	Semantics
`a || b`	Match `a` or `b` in sequence. equivalent to `a >> -b | b`

Attributes

See Compound Attribute Notation.

Expression	Attribute

`a || b`	`a: A, b: B --> (a || b): tuple<A, B>`
	`a: A, b: Unused --> (a || b): A`
	`a: Unused, b: B --> (a || b): B`
	`a: Unused, b: Unused --> (a || b): Unused`
	
	`a: A, b: A --> (a || b): vector<A>`
	`a: vector<A>, b: A --> (a || b): vector<A>`
	`a: A, b: vector<A> --> (a || b): vector<A>`
	`a: vector<A>, b: vector<A> --> (a || b): vec↵`
	`tor<A>`

Complexity

The overall complexity of the sequential-or parser is defined by the sum of the complexities of its elements. The complexity of the sequential-or itself is O(N), where N is the number of elements in the sequence.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::int_;
```

Correctly parsing a number with optional fractional digits:

```
test_parser("123.456", int_ || ('.' >> int_));  // full
test_parser("123", int_ || ('.' >> int_));      // just the whole number
test_parser(".456", int_ || ('.' >> int_));     // just the fraction
```

A naive but incorrect solution would try to do this using optionals (e.g.):

```
int_ >> -('.' >> int_)  // will not match ".456"
-int_ >> ('.' >> int_)  // will not match "123"
-int_ >> -('.' >> int_) // will match empty strings! Ooops.
```

Stream

This module includes the description of the different variants of the `stream` parser. It can be used to utilize existing streaming operators (`operator>>(std::istream&, ...)`) for input parsing.

Header

```
// forwards to <boost/spirit/home/qi/stream.hpp>
#include <boost/spirit/include/qi_stream.hpp>
```

Also, see Include Structure.

Stream (`stream`, `wstream`, etc.)

Description

The `stream_parser` is a primitive which allows to use pre-existing standard streaming operators for input parsing integrated with *Spirit.Qi*. It provides a wrapper parser dispatching the underlying input stream to the stream operator of the corresponding attribute type to be parsed. Any value `a` to be parsed using the `stream_parser` will result in invoking the standard streaming operator for its type `A`, for instance:

```
std::istream& operator>> (std::istream&, A&);
```

Header

```
// forwards to <boost/spirit/home/qi/stream.hpp>
#include <boost/spirit/include/qi_stream.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::stream // alias: boost::spirit::qi::stream`
`boost::spirit::wstream // alias: boost::spirit::qi::wstream`

Synopsis

```
template <typename Char, typename Attrib>
struct stream_parser;
```

Template parameters

Parameter	Description	Default
`Char`	The character type to use to generate the input. This type will be used while assigning the generated characters to the underlying input iterator.	`char`
`Attrib`	The type of the attribute the `stream_parser` is expected to parse its input into.	`spirit::hold_any`

Model of

`PrimitiveParser`

Notation

`s` A variable instance of any type with a defined matching streaming `operator>>()` or a Lazy Argument that evaluates to any type with a defined matching streaming `operator>>()`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Description
`stream`	Call the streaming `operator>>()` for the type of the mandatory attribute. The input recognized by this operator will be the result of the `stream` parser. This parser never fails (unless the underlying input stream reports an error). The character type of the I/O istream is assumed to be `char`.
`wstream`	Call the streaming `operator>>()` for the type of the mandatory attribute. The input recognized by this operator will be the result of the `wstream` parser. This parser never fails (unless the underlying input stream reports an error). The character type of the I/O istream is assumed to be `wchar_t`.

All parsers listed in the table above are predefined specializations of the `stream_parser<Char>` basic stream parser type described below. It is possible to directly use this type to create stream parsers using an arbitrary underlying character type.

Expression	Semantics
`stream_parser< Char, Attrib >()`	Call the streaming `operator>>()` for the type of the optional attribute, `Attrib`. The input recognized by this operator will be the result of the `stream_parser<>` parser. This parser never fails (unless the underlying input stream reports an error). The character type of the I/O istream is assumed to be `Char`

Additional Requirements

All of the stream parsers listed above require the type of the value to parse (the associated attribute) to implement a streaming operator conforming to the usual I/O streams conventions (where `attribute_type` is the type of the value to recognize while parse):

```
template <typename Istream>
Istream& operator>> (Istream& os, attribute_type& attr)
{
    // type specific input parsing
    return os;
}
```

This operator will be called by the stream parsers to gather the input for the attribute of type `attribute_type`.

Note

If the `stream` parser is invoked inside a `match` (or `phrase_match`) stream manipulator the `Istream` passed to the `operator>>()` will have registered (imbued) the same standard locale instance as the stream the `match` (or `phrase_match`) manipulator has been used with. This ensures all facets registered (imbued) with the original I/O stream object are used during input parsing.

Attributes

Expression	Attribute
`stream`	`spirit::hold_any`
`wstream`	`spirit::hold_any`
`stream_parser<Char, Attrib>()`	`Attrib`

Important

The attribute type `spirit::hold_any` exposed by some of the stream parsers is semantically and syntactically equivalent to the type implemented by Boost.Any. It has been added to *Spirit* as it has better performance and a smaller footprint than Boost.Any.

Complexity

O(N), where N is the number of characters consumed by the stream parser

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

A class definition used in the examples:

```
// a simple complex number representation z = a + bi
struct complex
{
    complex (double a = 0.0, double b = 0.0)
      : a(a), b(b)
    {}

    double a;
    double b;
};

// define streaming operator for the type complex
std::istream&
operator>> (std::istream& is, complex& z)
{
    char lbrace = '\0', comma = '\0', rbrace = '\0';
    is >> lbrace >> z.a >> comma >> z.b >> rbrace;
    if (lbrace != '{' || comma != ',' || rbrace != '}')
        is.setstate(std::ios_base::failbit);
    return is;
}
```

Using declarations and variables:

```
using boost::spirit::qi::stream;
using boost::spirit::qi::stream_parser;
```

Parse a simple string using the operator>>(istream&, std::string&);

```
std::string str;
test_parser_attr("abc", stream, str);
std::cout << str << std::endl;
```

Parse our complex type using the operator>>(istream&, complex&);

```
complex c;
test_parser_attr("{1.0,2.5}", stream_parser<char, complex>(), c);
std::cout << c.a << "," << c.b << std::endl;
```

String

This module includes parsers for strings. Currently, this module includes the literal and string parsers and the symbol table.

Module Header

```
// forwards to <boost/spirit/home/qi/string.hpp>
#include <boost/spirit/include/qi_string.hpp>
```

Also, see Include Structure.

String (`string`, `lit`)

Description

The `string` parser matches a string of characters. The `string` parser is an implicit lexeme: the `skip` parser is not applied in between characters of the string. The `string` parser has an assocaiated Character Encoding Namespace. This is needed when doing basic operations such as inhibiting case sensitivity. Examples:

```
string("Hello")
string(L"Hello")
string(s) // s is a std::string
```

`lit`, like `string`, also matches a string of characters. The main difference is that `lit` does not synthesize an attribute. A plain string like `"hello"` or a `std::basic_string` is equivalent to a `lit`. Examples:

```
"Hello"
lit("Hello")
lit(L"Hello")
lit(s) // s is a std::string
```

Header

```
// forwards to <boost/spirit/home/qi/string/lit.hpp>
#include <boost/spirit/include/qi_lit.hpp>
```

Namespace

Name
`boost::spirit::lit // alias: boost::spirit::qi::lit`
`ns::string`

In the table above, `ns` represents a Character Encoding Namespace.

Model of

`PrimitiveParser`

Notation

`s` A String or a Lazy Argument that evaluates to a String.

`ns` A Character Encoding Namespace.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`s`	Create string parser from a string, `s`.
`lit(s)`	Create a string parser from a string, `s`.
`ns::string(s)`	Create a string parser with `ns` encoding from a string, `s`.

Attributes

Expression	Attribute
`s`	`unused`
`lit(s)`	`unused`
`ns::string(s)`	`std::basic_string<T>` where `T` is the underlying character type of `s`.

Complexity

O(N)

where `N` is the number of characters in the string to be parsed.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::lit;
using boost::spirit::ascii::string;
```

Basic literals:

```
test_parser("boost", "boost");          // plain literal
test_parser("boost", lit("boost"));     // explicit literal
test_parser("boost", string("boost"));  // ascii::string
```

From a `std::string`

```
std::string s("boost");
test_parser("boost", s);            // direct
test_parser("boost", lit(s));       // explicit
test_parser("boost", string(s));    // ascii::string
```

Lazy strings using Phoenix

```
namespace phx = boost::phoenix;
test_parser("boost", phx::val("boost"));            // direct
test_parser("boost", lit(phx::val("boost")));       // explicit
test_parser("boost", string(phx::val("boost")));    // ascii::string
```

Symbols (`symbols`)

Description

The class `symbols` implements a symbol table: an associative container (or map) of key-value pairs where the keys are strings. The `symbols` class can work efficiently with 8, 16, 32 and even 64 bit characters.

Traditionally, symbol table management is maintained seperately outside the grammar through semantic actions. Contrary to standard practice, the Spirit symbol table class `symbols` is-a parser, an instance of which may be used anywhere in the grammar specification. It is an example of a dynamic parser. A dynamic parser is characterized by its ability to modify its behavior at run time. Initially, an empty symbols object matches nothing. At any time, symbols may be added, thus, dynamically altering its behavior.

Header

```
// forwards to <boost/spirit/home/qi/string/symbols.hpp>
#include <boost/spirit/include/qi_symbols.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::qi::symbols`
`boost::spirit::qi::tst`
`boost::spirit::qi::tst_map`

Synopsis

```
template <typename Char, typename T, typename Lookup>
struct symbols;
```

Template parameters

Parameter	Description	Default
`Char`	The character type of the symbol strings.	`char`
`T`	The data type associated with each symbol.	`unused_type`
`Lookup`	The symbol search implementation	`tst<Char, T>`

Model of

`PrimitiveParser`

Notation

`Sym`	A `symbols` type.
`Char`	A character type.
`T`	A data type.
`sym`, `sym2`	`symbols` objects.
`sseq`	An STL container of strings.
`dseq`	An STL container of data with `value_type` `T`.
`s1`...`sN`	A String.

`d1...dN`	Objects of type `T`.
`f`	A callable function or function object.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveParser`.

Expression	Semantics
`Sym()`	Construct an empty symbols.
`Sym(sym)`	Copy construct a symbols from `sym2` (Another `symbols` object).
`Sym(sseq)`	Construct symbols from `sseq` (An STL container of strings).
`Sym(sseq, dseq)`	Construct symbols from `sseq` and `dseq` (An STL container of strings and an STL container of data with `value_type` `T`).
`sym = sym2`	Assign `sym2` to `sym`.
`sym = s1, s2, ..., sN`	Assign one or more symbols (`s1...sN`) to `sym`.
`sym += s1, s2, ..., sN`	Add one or more symbols (`s1...sN`) to `sym`.
`sym.add(s1)(s2)...(sN)`	Add one or more symbols (`s1...sN`) to `sym`.
`sym.add(s1, d1)(s2, d2)...(sN, dN)`	Add one or more symbols (`s1...sN`) with associated data (`d1...dN`) to `sym`.
`sym -= s1, s2, ..., sN`	Remove one or more symbols (`s1...sN`) from `sym`.
`sym.remove(s1)(s2)...(sN)`	Remove one or more symbols (`s1...sN`) from `sym`.
`sym.clear()`	Erase all of the symbols in `sym`.
`sym.at(s)`	Return a reference to the object associated with symbol, `s`. If `sym` does not already contain such an object, `at` inserts the default object `T()`.
`sym.find(s)`	Return a pointer to the object associated with symbol, `s`. If `sym` does not already contain such an object, `find` returns a null pointer.
`sym.for_each(f)`	For each symbol in `sym`, `s`, a `std::basic_string<Char>` with associated data, `d`, an object of type `T`, invoke `f(s, d)`.

Attributes

The attribute of `symbol<Char, T>` is `T`.

Complexity

The default implementation uses a Ternary Search Tree (TST) with complexity:

O(log n+k)

Where k is the length of the string to be searched in a TST with n strings.

TSTs are faster than hashing for many typical search problems especially when the search interface is iterator based. TSTs are many times faster than hash tables for unsuccessful searches since mismatches are discovered earlier after examining only a few characters. Hash tables always examine an entire key when searching.

An alternative implementation uses a hybrid hash-map front end (for the first character) plus a TST: `tst_map`. This gives us a complexity of

O(1 + log n+k-1)

This is found to be significantly faster than plain TST, albeit with a bit more memory usage requirements (each slot in the hash-map is a TST node). If you require a lot of symbols to be searched, use the `tst_map` implementation. This can be done by using `tst_map` as the third template parameter to the symbols class:

```
symbols<Char, T, tst_map<Char, T> > sym;
```

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::qi::symbols;
```

Symbols with data:

```
symbols<char, int> sym;

sym.add
    ("Apple", 1)
    ("Banana", 2)
    ("Orange", 3)
;

int i;
test_parser_attr("Banana", sym, i);
std::cout << i << std::endl;
```

When `symbols` is used for case-insensitive parsing (in a `no_case` directive), added symbol strings should be in lowercase. Symbol strings containing one or more uppercase characters will not match any input when symbols is used in a `no_case` directive.

```
symbols<char, int> sym;

sym.add
    ("apple", 1)    // symbol strings are added in lowercase...
    ("banana", 2)
    ("orange", 3)
;

int i;
// ...because sym is used for case-insensitive parsing
test_parser_attr("Apple", no_case[ sym ], i);
std::cout << i << std::endl;
test_parser_attr("ORANGE", no_case[ sym ], i);
std::cout << i << std::endl;
```

Karma - Writing Generators

Tutorials

Quick Start

Spirit.Karma - what's that?

Throughout the description of *Spirit.Karma* we will try to align ourselves very much with the documentation for *Spirit.Qi*. The reasons are manyfold:

- *Spirit.Karma* is the counterpart to *Spirit.Qi*. Some people say it's the Yin to *Spirit.Qi*'s Yang. *Spirit.Karma* is generating byte sequences from internal data structures as *Spirit.Qi* is parsing byte sequences into those (very same) internal data structures.
- Both libraries have an almost identical structure, very similar semantics, and are both built using identical tools. Both libraries implement a language casting the specifics of their domain (parsing and generating) into a simple interface.

Why should you use a generator library for such a simple thing as output generation? Programmers have been using `printf`, `std::stream` formatting, or `boost::format` for quite some time. The answer is - yes, for simple output formatting tasks those familiar tools might be a quick solution. But experience shows: as soon as the formatting requirements are becoming more complex output generation is getting more and more challanging in terms of readability, maintainabilty, and flexibility of the code. Last, but not least, it turns out that code using *Spirit.Karma* runs much faster than equivalent code using either of the 'straight' methods mentioned above (see here for some numbers: Performance of Numeric Generators)

You might argue that more complex tasks require more complex tools. But this turns out not to be the case! The whole Spirit library is designed to be simple to use, while being scalable from trivial to very complicated applications.

In terms of development simplicity and ease in deployment, the same is true for *Spirit.Karma* as has been described elsewhere in this documentation for *Spirit.Qi*: the entire library consists of only header files, with no libraries to link against or build. Just put the spirit distribution in your include path, compile and run. Code size? Very tight, essentially comparable to hand written code.

The *Spirit.Karma* tutorials are built in a walk through style, starting with elementary things growing step by step in complexity. And again: keep in mind output generation is the exact opposite of parsing. Everything you already learnt about parsing using *Spirit.Qi* is applicable to generating formatted output using *Spirit.Karma*. All you have to do is to look at *Spirit.Karma* as being a mirror image of *Spirit.Qi*.

Warming up

Learning how to use *Spirit.Karma* is really simple. We will start from trivial examples, ramping up as we go.

Trivial Example #1 Generating a number

Let's create a generator that will output a floating-point number:

```
double_
```

Easy huh? The above code actually instantiates a Spirit floating point generator (a built-in generator). Spirit has many pre-defined generators and consistent naming conventions will help you finding your way through the maze. Especially important to note is that things related to identical entities (as in this case, floating point numbers) are named identically in *Spirit.Karma* and in *Spirit.Qi*. Actually, both libraries are using the very same variable instance to refer to a floating point generator or parser: `double_`.

Trivial Example #2 Generating two numbers

Now, let's create a generator that will output a line consisting of two floating-point numbers.

```
double_ << double_
```

Here you see the familiar floating-point numeric generator `double_` used twice, once for each number. If you are used to see the `'>>'` operator for concatenating two parsers in *Spirit.Qi* you might wonder, what's that `'<<'` operator doing in there? We decided to distinguish generating and parsing of sequences the same way as the std::stream libraries do: we use operator `'>>'` for input (parsing), and operator `'<<'` for output (generating). Other than that there is no significant difference. The above program creates a generator from two simpler generators, glueing them together with the sequence operator. The result is a generator that is a composition of smaller generators. Whitespace between numbers can implicitly be inserted depending on how the generator is invoked (see below).

Note

When we combine generators, we end up with a "bigger" generator, but it's still a generator. Generators can get bigger and bigger, nesting more and more, but whenever you glue two generators together, you end up with one bigger generator. This is an important concept.

Trivial Example #3 Generating one or more numbers

Now, creating output for two numbers is not too interesting. Let's create a generator that will output zero or more floating-point numbers in a row.

```
*double_
```

This is like a regular-expression Kleene Star. We moved the `*` to the front for the same reasons we did in *Spirit.Qi*: we must work with the syntax rules of C++. But if you know regular expressions (and for sure you remember those C++ syntax rules) it will start to look very familiar in a matter of a very short time.

Any expression that evaluates to a generator may be used with the Kleene Star. Keep in mind, though, that due to C++ operator precedence rules you may need to put the expression in parentheses for complex expressions. As above, whitespace can be inserted implicitely in between the generated numbers, if needed.

Trivial Example #4 Generating a comma-delimited list of numbers

We follow the lead of *Spirit.Qi*'s warming up section and will create a generator that produces a comma-delimited list of numbers.

```
double_ << *(lit(',') << double_)
```

Notice `lit(',')`. It is a literal character generator that simply generates the comma `','`. In this case, the Kleene Star is modifying a more complex generator, namely, the one generated by the expression:

```
(lit(',') << double_)
```

Note that this is a case where the parentheses are necessary. The Kleene Star encloses the complete expression above, repeating the whole pattern in the generated output zero or more times.

Let's Generate!

We're done with defining the generator. All that's left is to invoke the generator to do its work. For now, we will use the `generate_delimited` function. One overload of this function accepts four arguments:

1. An output iterator accepting the generated characters
2. The generator expression
3. Another generator called the delimiting generator
4. The data to format and output

While comparing this minimal example with an equivalent parser example we notice a significant difference. It is possible (and actually, it makes a lot of sense) to use a parser without creating any internal representation of the parsed input (i.e. without 'producing' any data from the parsed input). Using a parser in this mode checks the provided input against the given parser expression allowing to verify whether the input is parsable. For generators this mode doesn't make any sense. What is output generation without generating any output? So we always will have to supply the data the output should be generated from. In our example we supply a vector of `double` numbers as the last parameter to the function `generate_delimited` (see code below).

In this example, we wish to delimit the generated numbers by spaces. Another generator named `space` is included in Spirit's repertoire of predefined generators. It is a very trivial generator that simply produces spaces. It is the equivalent to writing `lit(' ')`, or simply `' '`. It has been implemented for similarity with the corresponding predefined `space` parser. We will use `space` as our delimiter. The delimiter is the one responsible for inserting characters in between generator elements such as the `double_` and `lit`.

Ok, so now let's generate (for the complete source code of this example please refer to num_list1.cpp).

```
template <typename OutputIterator>
bool generate_numbers(OutputIterator& sink, std::list<double> const& v)
{
    using karma::double_;
    using karma::generate_delimited;
    using ascii::space;

    bool r = generate_delimited(
        sink,                           // destination: output iterator
        double_ << *(',' << double_),   // the generator
        space,                          // the delimiter-generator
        v                               // the data to output
    );
    return r;
}
```

Note

You might wonder how a `vector<double>`, which is actually a single data structure, can be used as an argument (we call it attribute) to a sequence of generators. This seems to be counter intuitive and doesn't match with your experience of using `printf`, where each formatting placeholder has to be matched with a corresponding argument. Well, we will explain this behavior in more detail later in this tutorial. For now just consider this to be a special case, implemented on purpose to allow more flexible output formatting of STL containers: sequences accept a single container attribute if all elements of this sequence accept attributes compatible with the elements held by this container.

The generate function returns `true` or `false` depending on the result of the output generation. As outlined in different places of this documentation, a generator may fail for different reasons. One of the possible reasons is an error in the underlying output iterator (memory exhausted or disk full, etc.). Another reason might be that the data doesn't match the requirements of a particular generator.

Note

`char` and `wchar_t` operands

The careful reader may notice that the generator expression has `','` instead of `lit(',')` as the previous examples did. This is ok due to C++ syntax rules of conversion. Spirit provides << operators that are overloaded to accept a `char` or `wchar_t` argument on its left or right (but not both). An operator may be overloaded if at least one of its parameters is a user-defined type. In this case, the `double_` is the 2nd argument to `operator<<`, and so the proper overload of << is used, converting `','` into a character literal generator.

The problem with omiting the `lit` should be obvious: `'a' << 'b'` is not a spirit generator, it is a numeric expression, left-shifting the ASCII (or another encoding) value of `'a'` by the ASCII value of `'b'`. However, both `lit('a') << 'b'` and `'a' << lit('b')` are Spirit sequence generators for the letter `'a'` followed by `'b'`. You'll get used to it, sooner or later.

Note that we inlined the generator directly in the call to `generate_delimited`. Upon calling this function, the expression evaluates into a temporary, unnamed generator which is passed into the `generate_delimited` function, used, and then destroyed.

Here, we chose to make the generate function generic by making it a template, parameterized by the output iterator type. By doing so, it can put the generated data into any STL conforming output iterator.

Semantic Actions

In the previous section we mentioned a very important difference between parsers and generators. While parsers may be used without 'producing' any data, generators always need data to generate the output from. We mentioned one way of passing data to the generator by supplying it as a parameter to one of the main API functions (for instance `generate()` or `generate_delimited()`). But sometimes this is not possible or not desireable.

Very much like for *Spirit.Qi* we have semantic actions in *Spirit.Karma* as well. Semantic actions may be attached to any point in the grammar specification. These actions are C++ functions or function objects that are called whenever a part of the generator is about to be invoked. Say you have a generator `G`, and a C++ function `F`, you can make the generator call `F` just before it gets invoked by attaching `F`:

```
G[F]
```

The expression above links `F` to the generator, `G`.

Semantic actions in *Spirit.Qi* are invoked after a parser successfully matches its input and the matched value is passed into the semantic action. In *Spirit.Karma* the opposite happens. Semantic actions are called before its associated generator is invoked. They may provide the data required by the generator.

The function/function object signature depends on the type of the generator to which it is attached. The generator `double_` expects the number to generate. Thus, if we were to attach a function `F` to `double_`, we need `F` to be declared as:

```
void F(double& n);
```

where the function is expected to initialize the parameter `n` with the value to generate.

Important

Generally, and more formally, the semantic action `F` attached to a generator `G` needs to take a reference to the generator's attribute type as its first parameter. For more information about generator attributes please see the section Generator Attributes.

In the example above the function F takes a `double&` as its first parameter as the attribute of the `double_` generator happens to be a `double`.

There are actually 2 more arguments being passed (the generator context and a reference to a boolean 'pass' parameter). We don't need these, for now, but we'll see more on these other arguments later. *Spirit.Karma* allows us to bind a single argument function, like above. The other arguments are simply ignored.

To sum up, the possible signatures for semantic actions are:

```
void f(Attrib&);
void f(Attrib&, Context&);
void f(Attrib&, Context&, bool&);
```

Examples of Semantic Actions

In the following example we present various ways to attach semantic actions:

- Using a plain function pointer
- Using a simple function object
- Using Boost.Bind with a plain function
- Using Boost.Bind with a member function
- Using Boost.Lambda

Let's assume we have:

```
namespace client
{
    namespace karma = boost::spirit::karma;

    // A plain function
    void read_function(int& i)
    {
        i = 42;
    }

    // A member function
    struct reader
    {
        void print(int& i) const
        {
            i = 42;
        }
    };

    // A function object
    struct read_action
    {
        void operator()(int& i, unused_type, unused_type) const
        {
            i = 42;
        }
    };
}
```

Take note that with function objects, we need to have an `operator()` with 3 arguments. Since we don't care about the other two, we can use `unused_type` for these. We'll see more of `unused_type` elsewhere. Get used to it. `unused_type` is a Spirit supplied support class. Most of the time it stands for 'I don't care, just use the appropriate default'.

All following examples generate outputs of the form:

```
"{integer}"
```

An integer inside the curly braces.

The first example shows how to attach a plain function:

```
generate(outiter, '{' << int_[&read_function] << '}');
```

What's new? Well `int_` is the sibbling of `double_`. I'm sure you can guess what this generator does and what type of attribute it expects.

The next example shows how to attach a simple function object:

```
generate(outiter, '{' << int_[read_action()] << '}');
```

We can use Boost.Bind to 'bind' member functions:

```
reader r;
generate(outiter, '{' << int_[boost::bind(&reader::print, &r, _1)] << '}');
```

Likewise, we can also use Boost.Bind to 'bind' plain functions:

```
generate(outiter, '{' << int_[boost::bind(&read_function, _1)] << '}');
```

And last but not least, we can also use Boost.Lambda:

```
std::stringstream strm("42");
generate(outiter, '{' << int_[strm >> lambda::_1] << '}');
```

There are more ways to bind semantic action functions, but the examples above are the most common. Attaching semantic actions is the first hurdle one has to tackle when getting started with generating with Spirit. If you didn't do so yet, it is probably a good idea to familiarize yourself with the tools behind it such as Boost.Bind and Boost.Lambda.

The examples above can be found here: actions.cpp

Phoenix

Phoenix, a companion library bundled with Spirit, is specifically suited for binding semantic actions. It is like Boost.Lambda on steroids, with special custom features that make it easy to integrate semantic actions with Spirit. If your requirements go beyond simple to moderate generation, I suggest you use this library. Examples presented henceforth shall be using the Phoenix library exclusively.

Important

There are different ways to write semantic actions for *Spirit.Karma*: using plain functions, Boost.Bind, Boost.Lambda, or Phoenix. The latter three allow you to use special placeholders to control parameter placement (`_1`, `_2`, etc.). Each of those libraries has it's own implementation of the placeholders, all in different namespaces. You have to make sure not to mix placeholders with a library they don't belong to and not to use different libraries while writing a semantic action.

Generally, for Boost.Bind, use `::_1`, `::_2`, etc. (yes, these placeholders are defined in the globl namespace).

For Boost.Lambda use the placeholders defined in the namespace `boost::lambda`.

For semantic actions written using Phoenix use the placeholders defined in the namespace `boost::spirit`. Please note that all existing placeholders for your convenience are also available from the namespace `boost::spirit::karma`.

Complex - A first more complex generator

In this section we will develop a generator for complex numbers, allowing to represent a `std::complex` either as `(real, imag)` (where `real` and `imag` are the real and imaginary parts of the complex number) or as a simple `real` if the imaginary part happens to be equal to zero. This example will highlight the power of *Spirit.Karma* allowing to combine compile time definition of formatting rules with runtime based decisions which of the rules to apply. Also this time, we're using Boost.Phoenix to do the semantic actions.

Our goal is to allow for two different output formats to be applied depending on whether the imaginary part of the complex number is zero or not. Let's write both as a set of alternatives:

```
    '(' << double_ << ", " << double_ << ')'
|   double_
```

where the first alternative should be used for numbers having a non-zero imaginary part, while the second is for real numbers. Generally, alternatives are tried in the sequence of their definition as long until one of the expressions (as delimited by `'|'`) succeeds. If no generator expression succeeds the whole alternative fails.

If we left this formatting grammar as is our generator would always choose the first alternative. We need to add some additional rules allowing to make the first alternative fail. So, if the first alternative fails the second one will be chosen instead. The decision about whether to choose the first alternative has to be made at runtime as only then we actually know the value of the imaginary part

of the complex number. *Spirit.Karma* provides us with with a primitive generator `eps()`, which is usable as a semantic predicate. It has the property to 'succeed' generating only if its argument is true (while it never generates any output on its own).

```
double imag = ...;     // imaginary part

    eps(imag != 0) << '(' << double_ << ", " << double_ << ')'
|   double_
```

If one of the generator elements of a sequence fails the whole sequence will fail. This is exactly what we need, forcing the second alternative to be chosen for complex numbers with imaginary parts equal to zero.

Now on to the full example, this time with the proper semantic actions (the complete cpp file for this example can be found here: complex_number.cpp).

We will use the `std::complex` type for this and all subsequent related examples. And here you can see the full code of the generator allowing to output a complex number either as a pair of numbers (if the imaginary part is non-zero) or as a single number (if the complex is a real number):

```
template <typename OutputIterator>
bool generate_complex(OutputIterator sink, std::complex<double> const& c)
{
    using boost::spirit::karma::eps;
    using boost::spirit::karma::double_;
    using boost::spirit::karma::_1;
    using boost::spirit::karma::generate;

    return generate(sink,
        //  Begin grammar
        (
            eps(c.imag() != 0) <<
            '(' << double_[_1 = c.real()] << ", " << double_[_1 = c.imag()] << ')'
        |   double_[_1 = c.real()]
        )
        //  End grammar
    );
}
```

The `double_` generators have this semantic action attached:

```
_1 = n
```

which passes `n` to the first element of the generator the semantic action is attached to. Remember, semantic actions in *Spirit.Karma* are called before the corresponding generator is invoked and they are expected to provide the generator with the data to be used. The semantic action above assigns the value to be generated (`n`) to the generator (actually, the attribute of `double_`). `_1` is a Phoenix placeholder referring to the attribute of the generator the semantic action is attached to. If you need more information about semantic actions, you may want to read about them in this section: Semantic Actions.

These semantic actions are easy to understand but have the unexpected side effect of being slightly less efficient than it could be. In addition they tend to make the formatting grammar less readable. We will see in one of the next sections how it is possible to use other, built-in features of *Spirit.Karma* to get rid of the semantic actions altogether. When writing your grammars in Spirit you should always try to avoid semantic actions which is often possible. Semantic actions are really powerful tools but grammars tend to be more efficient and readable without them.

Complex - Made easier

In the previous section we showed how to format a complex number (i.e. a pair of doubles). In this section we will build on this example with the goal to avoid using semantic actions in the format specification. Let's have a look at the resulting code first, trying to understand it afterwards (the full source file for this example can be found here: complex_number_easier.cpp):

```
template <typename OutputIterator>
bool generate_complex(OutputIterator sink, std::complex<double> const& c)
{
    using boost::spirit::karma::double_;
    using boost::spirit::karma::omit;
    using boost::spirit::karma::generate;

    return generate(sink,

        //  Begin grammar
        (
           !double_(0.0) << '(' << double_ << ", " << double_ << ')'
        |   omit[double_] << double_ << omit[double_]
        ),
        //  End grammar

        c.imag(), c.real(), c.imag()     //  Data to output
    );
}
```

Let's cover some basic library features first.

Making Numeric Generators Fail

All Numeric Generators (such as `double_`, et.al.) take the value to emit from an attached attribute.

```
double d = 1.5;
generate(out, double_, d);       // will emit '1.5' (without the quotes)
```

Alternatively, they may be initialized from a literal value. For instance, to emit a constant `1.5` you may write:

```
generate(out, double_(1.5));     // will emit '1.5' as well (without the quotes)
```

The difference to a simple `1.5` or `lit(1.5)` is that the `double_(1.5)` consumes an attribute if one is available. Additionally, it compares its immediate value to the value of the supplied attribute, and fails if those are not equal.

```
double d = 1.5;
generate(out, double_(1.5), d);  // will emit '1.5' as long as d == 1.5
```

This feature, namely to succeed generating only if the attribute matches the immediate value, enables numeric generators to be used to dynamically control the way output is generated.

Note

Quite a few generators will fail if their immediate value is not equal to the supplied attribute. Among those are all Character Generators and all String Generators. Generally, all generators having a sibling created by a variant of `lit()` belong into this category.

Predicates - The Conditionals for Output Generators

In addition to the `eps` generator mentioned earlier *Spirit.Karma* provides two special operators enabling dynamic flow control: the And predicate (unary &) and the Not predicate (unary !). The main property of both predicates is to discard all output emitted by the generator they are attached to. This is equivalent to the behaviour of predicates used for parsing. There the predicates do not consume any input allowing to look ahead in the input stream. In Karma, the and predicate succeeds as long as its associated generator suceeds, while the not predicate succeeds only if its associated generator fails.

Note

The generator predicates in *Spirit.Karma* consume an attribute, if available. This makes them behave differently from predicates in *Spirit.Qi*, where they do not expose any attribute. This is because predicates allow to make decisions based on data available only at runtime. While in *Spirit.Qi* during parsing the decision is made based on looking ahead a few more input tokens, in *Spirit.Karma* the criteria has to be supplied by the user. The simplest way to do this is by providing an attribute.

As an example, the following generator succeeds generating

```
double d = 1.0;
BOOST_ASSERT(generate(out, &double_(1.0), d));    // succeeds as d == 1.0
```

while this one will fail:

```
double d = 1.0;
BOOST_ASSERT(!generate(out, !double_(1.0), d));   // fails as d == 1.0
```

Neither of these will emit any output. The predicates discard everything emitted by the generators they are applied to.

Ignoring Supplied Attributes

Sometimes it is desirable to 'skip' (i.e. ignore) a provided attribute. This happens for instance in alternative generators, where some of the alternatives need to extract only part of the overall attribute passed to the alternative generator. *Spirit.Karma* has a special pseudo generator for that: the directive `omit[]`. This directive consumes an attribute of the type defined by its embedded generator but it does not emit any output.

Note

The *Spirit.Karma* `omit` directive does the 'opposite' of the directive of the same name in *Spirit.Qi*. While the `omit` in *Spirit.Qi* consumes input without exposing an attribute, its *Spirit.Karma* counterpart consumes an attribute without emitting any output.

Putting everything together

Very similar to our first example ealier we use two alternatives to allow for the two different output formats depending on whether the imaginery part of the complex number is equal to zero or not. The first alternative is executed if the imaginary part is not zero, the second alternative otherwise. This time we make the decision during runtime using the Not predicate (unary `!`) combined with the feature of many Karma primitive generators to *fail* under certain conditions. Here is the first alternative again for your reference:

```
!double_(0.0) << '(' << double_ << ", " << double_ << ')'
```

The generator `!double_(0.0)` does several things. First, because of the Not predicate (unary `!`), it succeeds only if the `double_(0.0)` generator *fails*, making the whole first alternative fail otherwise. Second, the `double_(0.0)` generator succeeds only if the value of its attribute is equal to its immediate parameter (i.e. in this case `0.0`). And third, the not predicate does not emit any output (regardless whether it succeeds or fails), discarding any possibly emitted output from the `double_(0.0)`.

As we pass the imaginery part of the complex number as the attribute value for the `!double_(0.0)`, the overall first alternative will be chosen only if it is not equal to zero (the `!double_(0.0)` does not fail). That is exactly what we need!

Now, the second alternative has to emit the real part of the complex number only. In order to simplify the overall grammar we strive to unify the attribute types of all alternatives. As the attribute type exposed by the first alternative is `tuple<double, double, double>`, we need to skip the first and last element of the attribute (remember, we pass the real part as the second attribute element). We achieve this by using the `omit[]` directive:

```
omit[double_] << double_ << omit[double_]
```

The overall attribute of this expression is `tuple<double, double, double>`, but the `omit[]` 'eats up' the first and the last element. The output emitted by this expression consist of a single generated double representing the second element of the tuple, i.e. the real part of our complex number.

Important

Generally, it is preferrable to use generator constructs not requiring semantic actions. The reason is that semantic actions often use constructs like: `double_[_1 = c.real()]`. But this assignment is a real one! The data is in fact *copied* to the attribute value of the generator the action is attached to. On the other hand, grammars without any semantic actions usually don't have to copy the attributes, making them more efficient.

Number List - Printing Numbers From a std::vector

Using the List Operator

The C++ Standard library lacks an important feature, namely the support for any formatted output of containers. Sure, it's fairly easy to write a custom routine to output a specific container, but doing so over and over again is tedious at best. In this section we will demonstrate some more of the capabilities of *Spirit.Karma* for generating output from arbitrary STL containers. We will build on the example presented in an earlier section (see Warming Up).

The full source code of the example shown in this section can be found here: num_list2.cpp.

This time we take advantage of Karma's List (%) operator. The semantics of the list operator are fully equivalent to the semantics of the sequence we used before. The generator expression

```
double_ << *(',' << double_)
```

is semantically equivalent to the generator expression

```
double_ % ','
```

simplifying the overall code. The list operator's attribute is compatible with any STL container as well. For a change we use a `std::vector<double>` instead of the `std::list<double>` we used before. Additionally, the routine `generate_numbers` takes the container as a template paramter, so it will now work with any STL container holding `double` numbers.

```
template <typename OutputIterator, typename Container>
bool generate_numbers(OutputIterator& sink, Container const& v)
{
    using boost::spirit::karma::double_;
    using boost::spirit::karma::generate_delimited;
    using boost::spirit::ascii::space;

    bool r = generate_delimited(
        sink,                           // destination: output iterator
        double_ % ',',                  // the generator
        space,                          // the delimiter-generator
        v                               // the data to output
    );
    return r;
}
```

Note

Despite the container being a template parameter, the *Spirit.Karma* formatting expression (`double_ % ','`) does not depend on the actual type of the passed container. The only precondition to be met here is that the elements stored in the container have to be convertible to `double`.

Generate Output from Arbitrary Data

The output routine developed above is still not generically usable for all types of STL containers and for arbitrary elements stored in them. In order to be usable the items stored in the container still need to be convertible to a `double`. Fortunately *Spirit.Karma* is capable to output arbitrary data types while using the same format description expression. It implements the `stream` generators which are able to consume any attribute type as long as a matching standard streaming operator is defined. I.e. for any attribute type `Attrib` a function:

```
std::ostream& operator<< (std::ostream&, Attrib const&);
```

needs to be available. The `stream` generator will use the standard streaming operator to generate the output.

The following example modifies the code shown above to utilize the `stream` operator, which makes it compatible with almost any data type. We implement a custom data type `complex` to demonstrate this. The example shows how it is possible to integrate this (or any other) custom data type into the *Spirit.Karma* generator framework.

This is the custom data structure together with the required standard streaming operator:

```
// a simple complex number representation z = a + bi
struct complex
{
    complex (double a, double b = 0.0) : a(a), b(b) {}

    double a;
    double b;
};

// the streaming operator for the type complex
std::ostream&
operator<< (std::ostream& os, complex const& z)
{
    os << "{" << z.a << "," << z.b << "}";
    return os;
}
```

And this is the actual call to generate the output from a vector of those. This time we interleave the generated output with newline breaks (see `eol`), putting each complex number onto a separate line:

```
template <typename OutputIterator, typename Container>
bool generate_numbers(OutputIterator& sink, Container const& v)
{
    using boost::spirit::karma::stream;
    using boost::spirit::karma::generate;
    using boost::spirit::karma::eol;

    bool r = generate(
        sink,                           // destination: output iterator
        stream % eol,                   // the generator
        v                               // the data to output
    );
    return r;
}
```

The code shown is fully generic and can be used with any STL container as long as the data items stored in that container implement the standard streaming operator.

The full source code of the example presented in this section can be found here: num_list3.cpp.

Matrix of Numbers - Printing Numbers From a Matrix

In this section we will discuss the possibilities of *Spirit.Karma* when it comes to generating output from more complex - but still regular - data structures. For simplicity we will use a `std::vector<std::vector<int> >` as a poor man's matrix representation. But even if the data structure seems to be very simple, the presented principles are applicable to more complex, or custom data structures as well. The full source code of the example discussed in this section can be found here: num_matrix.cpp.

Quick Reference

This quick reference section is provided for convenience. You can use this section as sort of a "cheat-sheet" on the most commonly used Karma components. It is not intended to be complete, but should give you an easy way to recall a particular component without having to dig up on pages upon pages of reference documentation.

Common Notation

Notation

`G`	Generator type

`g, a, b, c, d`	Generator objects
`A, B, C, D`	Attribute types of generators `a`, `b`, `c`, and `d`
`I`	The iterator type used for generation
`Unused`	An `unused_type`
`Context`	The enclosing rule's `Context` type
`attrib`	An attribute value
`Attrib`	An attribute type
`b`	A boolean expression
`B`	A type to be interpreted in boolean expressions
`fg`	A (lazy generator) function with signature `G(Unused, Context)`
`fa`	A (semantic action) function with signature `void(Attrib&, Context, bool&)`. The third parameter is a boolean flag that can be set to false to force the generator to fail. Both `Context` and the boolean flag are optional.
`outiter`	An output iterator to receive the generated output
`Ch`	Character-class specific character type (See Character Class Types)
`ch, ch2`	Character-class specific character (See Character Class Types)
`charset`	Character-set specifier string (example: `"a-z0-9"`)
`str`	Character-class specific string (See Character Class Types)
`Str`	Attribute of `str`: `std::basic_string<T>` where `T` is the underlying character type of `str`
`num`	Numeric literal, any integer or real number type
`Num`	Attribute of `num`: any integer or real number type
`tuple<>`	Used as a placeholder for a fusion sequence
`vector<>`	Used as a placeholder for an STL container
`variant<>`	Used as a placeholder for a boost::variant
`optional<>`	Used as a placeholder for a boost::optional

Karma Generators

Character Generators

See here for more information about Character Generators.

Expression	Attribute	Description
`ch`	`Unused`	Generate `ch`
`lit(ch)`	`Unused`	Generate `ch`
`char_`	`Ch`	Generate character supplied as the attribute
`char_(ch)`	`Ch`	Generate `ch`, if an attribute is supplied it must match
`char_("c")`	`Ch`	Generate a single char string literal, `c`, if an attribute is supplied it must match
`char_(ch, ch2)`	`Ch`	Generate the character supplied as the attribute, if it belongs to the character range from `ch` to `ch2`
`char_(charset)`	`Ch`	Generate the character supplied as the attribute, if it belongs to the character set `charset`
`alnum`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::isalnum` in the character set defined by `NS`
`alpha`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::isalpha` in the character set defined by `NS`
`blank`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::isblank` in the character set defined by `NS`
`cntrl`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::iscntrl` in the character set defined by `NS`
`digit`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::isdigit` in the character set defined by `NS`
`graph`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::isgraph` in the character set defined by `NS`
`print`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::isprint` in the character set defined by `NS`

Expression	Attribute	Description
`punct`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::ispunct` in the character set defined by `NS`
`space`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::isspace`, or a single space character in the character set defined by `NS`
`xdigit`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::isxdigit` in the character set defined by `NS`
`lower`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::islower` in the character set defined by `NS`
`upper`	`Ch`	Generate the character supplied as the attribute if it satisfies the concept of `std::isupper` in the character set defined by `NS`

String Generators

See here for more information about String Generators.

Expression	Attribute	Description
`str`	`Unused`	Generate `str`
`lit(str)`	`Unused`	Generate `str`
`string`	`Str`	Generate string supplied as the attribute
`string(str)`	`Str`	Generate `str`, if an attribute is supplied it must match

Real Number Generators

See here for more information about Numeric Generators.

Expression	Attribute	Description
`lit(num)`	`Unused`	Generate `num`
`float_`	`float`	Generate a real number from a `float`
`float_(num)`	`float`	Generate `num` as a real number from a `float`, if an attribute is supplied it must match
`double_`	`double`	Generate a real number from a `double`
`double_(num)`	`double`	Generate a `num` as a real number from a `double`, if an attribute is supplied it must match
`long_double`	`long double`	Generate a real number from a `long double`
`long_double(num)`	`long double`	Generate `num` as a real number from a `long double`, if an attribute is supplied it must match

`real_generator<`
`  Num, Policies`
`>()`
	`Num`	Generate a real number `Num` using the supplied real number formatting policies

`real_generator<`
`  Num, Policies`
`>()(num)`
	`Num`	Generate real number `num` as a `Num` using the supplied real number formatting policies, if an attribute is supplied it must match

Integer Generators

Expression	Attribute	Description
`lit(num)`	`Unused`	Generate `num`
`short_`	`short`	Generate a short integer
`short_(num)`	`short`	Generate `num` as a short integer, if an attribute is supplied it must match
`int_`	`int`	Generate an int
`int_(num)`	`int`	Generate `num` as an int, if an attribute is supplied it must match
`long_`	`long`	Generate a long integer
`long_(num)`	`long`	Generate `num` as long integer, if an attribute is supplied it must match
`long_long`	`long long`	Generate a long long
`long_long(num)`	`long long`	Generate `num` as a long long, if an attribute is supplied it must match

`int_generator<`
`  Num, Radix, force_sign`
`>()`
	`Num`	Generate a `Num`

`int_generator<`
`  Num, Radix, force_sign`
`>()(num)`
	`Num`	Generate a `num` as a `Num`, if an attribute is supplied it must match

Unsigned Integer Generators

Expression	Attribute	Description
`lit(num)`	`Unused`	Generate `num`
`ushort_`	`unsigned short`	Generate an unsigned short integer
`ushort_(num)`	`unsigned short`	Generate `num` as an unsigned short integer, if an attribute is supplied it must match
`uint_`	`unsigned int`	Generate an unsigned int
`uint_(num)`	`unsigned int`	Generate `num` as an unsigned int, if an attribute is supplied it must match
`ulong_`	`unsigned long`	Generate an unsigned long integer
`ulong_(num)`	`unsigned long`	Generate `num` as an unsigned long integer, if an attribute is supplied it must match
`ulong_long`	`unsigned long long`	Generate an unsigned long long
`ulong_long(num)`	`unsigned long long`	Generate `num` as an unsigned long long, if an attribute is supplied it must match
`bin`	`unsigned int`	Generate a binary integer from an `unsigned int`
`oct`	`unsigned int`	Generate an octal integer from an `unsigned int`
`hex`	`unsigned int`	Generate a hexadecimal integer from an `unsigned int`

`uint_generator<`
`  Num, Radix`
`>()`
	`Num`	Generate an unsigned `Num`

`uint_generator<`
`  Num, Radix`
`>()(num)`
	`Num`	Generate an unsigned `num` as a `Num`, if an attribute is supplied it must match

Boolean Generators

Expression	Attribute	Description
`lit(num)`	`Unused`	Generate `num`
`bool_`	`bool`	Generate a boolean
`bool_(b)`	`bool`	Generate `b` as a boolean, if an attribute is supplied it must match

`bool_generator<`
`  B, Policies`
`>()`
	`B`	Generate a boolean of type `B`

`bool_generator<`
`  B, Policies`
`>()(b)`
	`B`	Generate a boolean `b` as a `B`, if an attribute is supplied it must match

Stream Generators

See here for more information about Stream Generators.

Expression	Attribute	Description
`stream`	`hold_any`	Generate narrow character (`char`) based output using the matching streaming `operator<<()`
`stream(s)`	`Unused`	Generate narrow character (`char`) based output from the immediate argument `s` using the matching streaming `operator<<()`
`wstream`	`hold_any`	Generate wide character (`wchar_t`) based output using the matching streaming `operator<<()`
`wstream(s)`	`Unused`	Generate wide character (`wchar_t`) based output from the immediate argument `s` using the matching streaming `operator<<()`
`stream_generator<Char>()`	`hold_any`	Generate output based on the given character type (`Char`) using the matching streaming `operator<<()`
`stream_generator<Char>()(s)`	`Unused`	Generate output based on the given character type `Char` from the immediate argument `s` using the matching streaming `operator<<()`

Binary Generators

See here for more information about Binary Generators.

Expression	Attribute	Description
`byte_`	8 bits native endian	Generate an 8 bit binary
`word`	16 bits native endian	Generate a 16 bit binary in native endian representation
`big_word`	16 bits big endian	Generate a 16 bit binary in big endian representation
`little_word`	16 bits little endian	Generate a 16 bit binary in little endian representation
`dword`	32 bits native endian	Generate a 32 bit binary in native endian representation
`big_dword`	32 bits big endian	Generate a 32 bit binary in big endian representation
`little_dword`	32 bits little endian	Generate a 32 bit binary in little endian representation
`qword`	64 bits native endian	Generate a 64 bit binary in native endian representation
`big_qword`	64 bits big endian	Generate a 64 bit binary in big endian representation
`little_qword`	64 bits little endian	Generate a 64 bit binary in little endian representation
`pad(num)`	`Unused`	Generate additional null bytes allowing to align generated output with memory addresses divisible by `num`.

Auxiliary Generators

See here for more information about Auxiliary Generators.

Expression	Attribute	Description
`attr_cast<Exposed>(a)`	`Exposed`	Invoke `a` while supplying an attribute of type `Exposed`.
`eol`	`Unused`	Generate the end of line (`\n`)
`eps`	`Unused`	Generate an empty string
`eps(b)`	`Unused`	If `b` is true, generate an empty string
`lazy(fg)`	Attribute of `G` where `G` is the return type of `fg`	Invoke `fg` at generation time, returning a generator `g` which is then called to generate.
`fg`	see `lazy(fg)` above	Equivalent to `lazy(fg)`

Generator Operators

See here for more information about Generator Operators.

Expression	Attribute	Description
`!a`	`A`	Not predicate. Ensure that `a` does not succeed generating, but don't create any output
`&a`	`A`	And predicate. Ensure that `a` does succeed generating, but don't create any output
`-a`	`optional<A>`	Optional. Generate `a` zero or one time
`*a`	`vector<A>`	Kleene. Generate `a` zero or more times
`+a`	`vector<A>`	Plus. Generate `a` one or more times
`a | b`	`variant<A, B>`	Alternative. Generate `a` or `b`
`a << b`	`tuple<A, B>`	Sequence. Generate `a` followed by `b`
`a % b`	`vector<A>`	List. Generate `a` delimited `b` one or more times

For more information about the attribute propagation rules implemented by the compound generators please see Generator Compound Attribute Rules.

Generator Directives

See here for more information about Generator Directives.

Expression	Attribute	Description
`lower[a]`	A	Generate a as lower case
`upper[a]`	A	Generate a as upper case
`left_align[a]`	A	Generate a left aligned in column of width `BOOST_KARMA_DEFAULT_FIELD_LENGTH`
`left_align(num)[a]`	A	Generate a left aligned in column of width `num`
`left_align(num, g)[a]`	A	Generate a left aligned in column of width `num` while using `g` to generate the necessary padding
`center[a]`	A	Generate a centered in column of width `BOOST_KARMA_DEFAULT_FIELD_LENGTH`
`center(num)[a]`	A	Generate a centered in column of width `num`
`center(num, g)[a]`	A	Generate a centered in column of width `num` while using `g` to generate the necessary padding
`right_align[a]`	A	Generate a right aligned in column of width `BOOST_KARMA_DEFAULT_FIELD_LENGTH`
`right_align(num)[a]`	A	Generate a right aligned in column of width `num`
`right_align(num, g)[a]`	A	Generate a right aligned in column of width `num` while using `g` to generate the necesssary padding
`maxwidth[a]`	A	Generate a truncated to column of width `BOOST_KARMA_DEFAULT_FIELD_MAXWIDTH`
`maxwidth(num)[a]`	A	Generate a truncated to column of width `num`
`repeat[a]`	`vector<A>`	Repeat a zero or more times
`repeat(num)[a]`	`vector<A>`	Repeat a `num` times
`repeat(num1, num2)[a]`	`vector<A>`	Repeat a `num1` to `num2` times
`repeat(num, inf)[a]`	`vector<A>`	Repeat a `num` or more times
`verbatim[a]`	A	Disable delimited generation for a

Expression	Attribute	Description
`delimit[a]`	`A`	Reestablish the delimiter that got inhibited by verbatim
`delimit(d)[a]`	`A`	Use `d` as a delimiter for generating `a`
`omit[a]`	`A`	Consume the attribute type of `a` without generating anything
`buffer[a]`	`A`	Temporarily intercept the output generated by `a`, flushing it only after `a` succeeded

Generator Semantic Actions

Expression	Attribute	Description
`g[fa]`	Attribute of `g`	Call semantic action `fa` before invoking `g`

Compound Attribute Rules

Notation

The notation we use is of the form:

```
a: A, b: B, ... --> composite-expression: composite-attribute
```

`a`, `b`, etc. are the operands. `A`, `B`, etc. are the operand's attribute types. `composite-expression` is the expression involving the operands and `composite-attribute` is the resulting attribute type of the composite expression.

For instance:

```
a: A, b: B --> (a << b): tuple<A, B>
```

which reads as: given, `a` and `b` are generators, and `A` is the type of the attribute of `a`, and `B` is the type of the attribute of `b`, then the type of the attribute of `a << b` will be `tuple<A, B>`.

Important

In the attribute tables, we will use `vector<A>` and `tuple<A, B...>` as placeholders only. The notation of `vector<A>` stands for *any STL container* holding elements of type `A` and the notation `tuple<A, B...>` stands for *any Boost.Fusion sequence* holding `A`, `B`, ... etc. elements. The notation of `variant<A, B, ...>` stands for *a Boost.Variant* capable of holding `A`, `B`, ... etc. elements. Finally, `Unused` stands for `unused_type`.

Compound Generator Attribute Types

Expression	Attribute

Sequence (<<)	`a: A, b: B --> (a << b): tuple<A, B>`
	`a: A, b: Unused --> (a << b): A`
	`a: Unused, b: B --> (a << b): B`
	`a: Unused, b: Unused --> (a << b): Unused`
	
	`a: A, b: A --> (a << b): vector<A>`
	`a: vector<A>, b: A --> (a << b): vector<A>`
	`a: A, b: vector<A> --> (a << b): vector<A>`
	`a: vector<A>, b: vector<A> --> (a << b): vec↵`
	`tor<A>`

Alternative (|)	`a: A, b: B --> (a | b): variant<A, B>`
	`a: A, b: Unused --> (a | b): A`
	`a: Unused, b: B --> (a | b): B`
	`a: Unused, b: Unused --> (a | b): Unused`
	`a: A, b: A --> (a | b): A`

Kleene (unary *)	`a: A --> *a: vector<A>` `a: Unused --> *a: Unused`
Plus (unary +)	`a: A --> +a: vector<A>` `a: Unused --> +a: Unused`
List (%)	`a: A, b: B --> (a % b): vector<A>` `a: Unused, b: B --> (a % b): Unused`
Repetition	`a: A --> repeat(...,...)[a]: vector<A>` `a: Unused --> repeat(...,...)[a]: Unused`
Optional (unary -)	`a: A --> -a: optional<A>` `a: Unused --> -a: Unused`
And predicate (unary &)	`a: A --> &a: A`
Not predicate (unary !)	`a: A --> !a: A`

Nonterminals

See here for more information about `Nonterminals`.

Notation

`RT`	Synthesized attribute. The rule or grammar's return type.

`Arg1`, `Arg2`, `ArgN`	Inherited attributes. Zero or more arguments.
`L1`, `L2`, `LN`	Zero or more local variables.
`r, r2`	Rules
`g`	A grammar
`p`	A generator expression
`my_grammar`	A user defined grammar

Terminology

Signature	`RT(Arg1, Arg2, ... ,ArgN)`. The signature specifies the synthesized (return value) and inherited (arguments) attributes.
Locals	`locals<L1, L2, ..., LN>`. The local variables.
Delimiter	The delimit-generator type

Template Arguments

`Iterator`	The iterator type you will use for parsing.
`A1`, `A2`, `A3`	Can be one of 1) Signature 2) Locals 3) Delimiter.

Expression	Description
`rule<OutputIterator, A1, A2, A3> r(name);`	Rule declaration. `OutputIterator` is required. `A1, A2, A3` are optional and can be specified in any order. `name` is an optional string that gives the rule its name, useful for debugging and error handling.
`rule<OutputIterator, A1, A2, A3> r(r2);`	Copy construct rule `r` from rule `r2`.
`r = r2;`	Assign rule `r2` to `r`. `boost::shared_ptr` semantics.
`r.alias()`	Return an alias of `r`. The alias is a generator that holds a reference to `r`. Reference semantics.
`r.copy()`	Get a copy of `r`.
`r.name(name)`	Set the name of a rule
`r.name()`	Get the name of a rule
`r = g;`	Rule definition
`r %= g;`	Auto-rule definition. The attribute of `g` should be compatible with the synthesized attribute of `r`. When `g` is successful, its attribute is automatically propagated to `r`'s synthesized attribute.

`template <typename OutputIterator>`
`struct my_grammar : grammar<OutputIterat↵`
`or, A1, A2, A3>`
`{`
`  my_grammar() : my_gram↵`
`mar::base_type(start, name)`
`  {`
`  // Rule definitions`
`  start = /* ... */;`
`  }`
`  rule<OutputIterator, A1, A2, A3> start;`
`  // more rule declarations...`
`};`
	Grammar definition. `name` is an optional string that gives the grammar its name, useful for debugging.

my_grammar<OutputIterator> g	Instantiate a grammar
`g.name(name)`	Set the name of a grammar
`g.name()`	Get the name of a grammar

Semantic Actions

Semantic Actions may be attached to any generator as follows:

```
g[f]
```

where `f` is a function with the signatures:

```
void f(Attrib&);
void f(Attrib&, Context&);
void f(Attrib&, Context&, bool&);
```

You can use Boost.Bind to bind member functions. For function objects, the allowed signatures are:

```
void operator()(Attrib&, unused_type, unused_type) const;
void operator()(Attrib&, Context&, unused_type) const;
void operator()(Attrib&, Context&, bool&) const;
```

The `unused_type` is used in the signatures above to signify 'don't care'.

For more information see Semantic Actions.

Phoenix

Boost.Phoenix makes it easier to attach semantic actions. You just inline your lambda expressions:

```
g[phoenix-lambda-expression]
```

Spirit.Karma provides some Boost.Phoenix placeholders to access important information from the `Attrib` and `Context` that are otherwise fiddly to extract.

Spirit.Karma specific Phoenix placeholders

`_1, _2, ... , _N`	Nth attribute of `g`
`_val`	The enclosing rule's synthesized attribute.
`_r1, _r2, ... , _rN`	The enclosing rule's Nth inherited attribute.
`_a, _b, ... , _j`	The enclosing rule's local variables (`_a` refers to the first).
`_pass`	Assign `false` to `_pass` to force a generator failure.

Important

All placeholders mentioned above are defined in the namespace `boost::spirit` and, for your convenience, are available in the namespace `boost::spirit::karma` as well.

For more information see Semantic Actions.

Reference

Generator Concepts

Spirit.Karma generators fall into a couple of generalized concepts. The *Generator* is the most fundamental concept. All *Spirit.Karma* generators are models of the *Generator* concept. *PrimitiveGenerator*, *UnaryGenerator*, *BinaryGenerator*, *NaryGenerator*, and *Nonterminal* are all refinements of the *Generator* concept.

The following sections provide details on these concepts.

Generator

Description

The *Generator* is the most fundamental concept. A Generator has a member function, `generate`, that accepts an `OutputIterator` and returns bool as its result. The iterator receives the data being generated. The Generator's `generate` member function returns `true` if the generator succeeds. Each Generator can represent a specific pattern or algorithm, or it can be a more complex generator formed as a composition of other Generators.

Notation

`g` A `Generator`.

`G` A `Generator` type.

`OutIter` An `OutputIterator` type.

`sink` An `OutputIterator` instance.

`Context` The generator's Context type.

`context` The generator's Context, or `unused`.

`delimit` A delimiter Generator, or `unused`.

`attrib` A Compatible Attributes, or `unused`.

Valid Expressions

In the expressions below, the behavior of the generator, `g`, as well as how `delimit` and `attrib` are handled by `g`, are left unspecified in the base `Generator` concept. These are specified in subsequent, more refined concepts and by the actual models therof.

For any Generator the following expressions must be valid:

Expression	Semantics	Return type
`g.generate(sink, context, delimit, attrib)`	Generate the output sequence by inserting the generated characters/tokens into `sink`. Use the `delimit` generator for delimiting. Return `true` if successful, otherwise return `false`.	`bool`
`g.what(context)`	Get information about a Generator.	`info`

Type Expressions

Expression	Description
`G::template attribute<Context>::type`	The Generator's attribute.
`traits::is_generator<G>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `G` is a Generator, `mpl::false_` otherwise (See MPL Boolean Constant).
`G::properties`	An `mpl::int_` (See MPL Integral Constant) holding a value from the `karma::generator_properties` enumeration. The default value is `generator_properties::no_properties`

Postcondition

Upon return from `g.generate` the following post conditions should hold:

- On successful generation, `sink` receives the generated characters/tokens sequence.
- No pre-delimits: `delimit` characters/tokens will not be emitted in front of any other output.
- The attribute `attrib` has not been modified.

Models

All generators in *Spirit.Karma* are models of the *Generator* concept.

PrimitiveGenerator

Description

PrimitiveGenerator is the most basic building block that the client uses to build more complex generators.

Refinement of

`Generator`

Post-delimit

Before exiting the `generate` member function, a PrimitiveGenerator is required to do a post-delimit. This will generate a single delimiting character/token sequence. Only PrimitiveGenerator's are required to perform this post-delimit. This is typically carried out through a call to `karma::delimit_out`:

```
karma::delimit_out(sink, delimit);
```

Type Expressions

Expression	Description
`traits::is_primitive_generator<G>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `G`, is a PrimitiveGenerator, `mpl::false_` otherwise (See MPL Boolean Constant).

Models

The following generators conform to this model:

- `eol`,
- `eps`,
- Numeric generators,
- Character generators.

FIXME Add more links to *PrimitiveGenerator* models here.

UnaryGenerator

Description

UnaryGenerator is a composite generator that has a single subject. The UnaryGenerator may change the behavior of its subject following the Delegate Design Pattern.

Refinement of

`Generator`

Notation

`g` A UnaryGenerator.

`G` A UnaryGenerator type.

Valid Expressions

In addition to the requirements defined in `Generator`, for any UnaryGenerator the following must be met:

Expression	Semantics	Return type
`g.subject`	Subject generator.	`Generator`

Type Expressions

Expression	Description
`G::subject_type`	The subject generator type.
`traits::is_unary_generator<G>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `G` is a UnaryGenerator, `mpl::false_` otherwise (See MPL Boolean Constant).

Invariants

For any UnaryGenerator, `G`, the following invariant always holds:

- `traits::is_generator<G::subject_type>::type` evaluates to `mpl::true_`

Models

The following generators conform to this model:

- Kleene Star (unary `*`) operator,
- Plus (unary `+`) operator,
- Optional (unary `-`) operator,
- And predicate (unary `&`) and Not predicate (unary `!`) operators,
- `left_align`, `center`, and `right_align` directives,
- `repeat` directive,
- `verbatim` directive,
- `delimit` directive,
- `lower` and `upper` directives,
- `maxwidth` directive,
- `buffer` directive,

- `omit` directive.

FIXME Add more links to models of UnaryGenerator concept

BinaryGenerator

Description

BinaryGenerator is a composite generator that has a two subjects, `left` and `right`. The BinaryGenerator allows its subjects to be treated in the same way as a single instance of a `Generator` following the Composite Design Pattern.

Refinement of

`Generator`

Notation

`g` A BinaryGenerator.

`G` A BinaryGenerator type.

Valid Expressions

In addition to the requirements defined in `Generator`, for any BinaryGenerator the following must be met:

Expression	Semantics	Return type
`g.left`	Left generator.	`Generator`
`g.right`	Right generator.	`Generator`

Type Expressions

Expression	Description
`G::left_type`	The left generator type.
`G::right_type`	The right generator type.
`traits::is_binary_generator<G>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `G` is a BinaryGenerator, `mpl::false_` otherwise (See MPL Boolean Constant).

Invariants

For any BinaryGenerator, `G`, the following invariants always hold:

- `traits::is_generator<G::left_type>::type` evaluates to `mpl::true_`
- `traits::is_generator<G::right_type>::type` evaluates to `mpl::true_`

Models

The following generators conform to this model:

- List (%).

FIXME Add more links to models of BinaryGenerator concept

NaryGenerator

Description

NaryGenerator is a composite generator that has one or more subjects. The NaryGenerator allows its subjects to be treated in the same way as a single instance of a `Generator` following the Composite Design Pattern.

Refinement of

`Generator`

Notation

`g` A NaryGenerator.

`G` A NaryGenerator type.

Valid Expressions

In addition to the requirements defined in `Generator`, for any NaryGenerator the following must be met:

Expression	Semantics	Return type
`g.elements`	The tuple of elements.	A Boost.Fusion Sequence of `Generator` types.

Type Expressions

Expression	Description
`g.elements_type`	Elements tuple type.
`traits::is_nary_generator<G>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `G` is a NaryGenerator, `mpl::false_` otherwise (See MPL Boolean Constant).

Invariants

For each element, `E`, in any NaryGenerator, `G`, the following invariant always holds:

- `traits::is_generator<E>::type` evaluates to `mpl::true_`

Models

The following generators conform to this model:

- Sequence (<<),
- Alternative (|).

FIXME Add more links to models of NaryGenerator concept

Nonterminal

Description

A Nonterminal is a symbol in a Parsing Expression Grammar production that represents a grammar fragment. Nonterminals may self reference to specify recursion. This is one of the most important concepts and the reason behind the word "recursive" in recursive descent generation.

Refinement of

`Generator`

Signature

Rules can have both consumed and inherited attributes. The rule's *Signature* specifies both the consumed and inherited attributes. The specification uses the function declarator syntax:

```
RT(A0, A1, A2, ..., AN)
```

where `RT` is the rule's consumed attribute and `A0` ... `AN` are the rule's inherited attributes.

Attributes

The rule models a C++ function. The rule's consumed attribute is analogous to the function return value as it is the type -exposed- by the rule. Its inherited attributes are analogous to function arguments. The inherited attributes (arguments) can be passed in just like any Lazy Argument, e.g.:

```
r(expr) // Evaluate expr at parse time and pass the result to the Nonterminal r
```

`_val`

The `boost::spirit::karma::_val` placeholder can be used in Phoenix semantic actions anywhere in the Nonterminal's definition. This Phoenix placeholder refers to the Nonterminal's (consumed) attribute. The `_val` placeholder acts like an immutable reference to the Nonterminal's attribute.

`_r1...r10`

The `boost::spirit::_r1`...`boost::spirit::r10` placeholders can be used in Phoenix semantic actions anywhere in the Nonterminal's definition. These Phoenix placeholders refer to the Nonterminal's inherited attributes.

Locals

Nonterminals can have local variables that will be created on the stack at runtime. A locals descriptor added to the Nonterminal declaration will give the Nonterminal local variables:

```
template <typename T0, typename T1, typename T2, ..., typename TN>
struct locals;
```

where `T0` ... `TN` are the types of local variables accessible in your Phoenix semantic actions using the placeholders:

- `boost::spirit::_a`
- `boost::spirit::_b`
- `boost::spirit::_c`
- `boost::spirit::_d`
- `boost::spirit::_e`
- `boost::spirit::_f`
- `boost::spirit::_g`
- `boost::spirit::_h`
- `boost::spirit::_i`

- `boost::spirit::_j`

which correspond to the Nonterminal's local variables `T0` ... `T9`.

Notation

`x`	A Nonterminal
`X`	A Nonterminal type
`arg1`, `arg2`, ..., `argN`	Lazy Arguments that evaluate to each of the Nonterminal's inherited attributes.

Valid Expressions

In addition to the requirements defined in `Generator`, for any Nonterminal the following must be met:

Expression	Semantics	Return type
`x`	In a generator expression, invoke Nonterminal `x`	`X`
`x(arg1, arg2, ..., argN)`	In a generator expression, invoke Nonterminal `x` passing in inherited attributes `arg1`...`argN`	`X`
`x.name(name)`	Set the name of a Nonterminal	`void`
`x.name()`	Get the name of a Nonterminal	`std::string`

Type Expressions

Expression	Description
`X::sig_type`	The Signature of `X`: An MPL Forward Sequence. The first element is the Nonterminal's consumed attribute type and the rest are the inherited attribute types.
`X::locals_type`	The local variables of `X`: An MPL Forward Sequence.

Models

- rule
- grammar

Basics

Lazy Argument

Some generators (e.g. primitives and non-terminals) may take in additional attributes. Such generators take the form:

```
g(a1, a2, ..., aN)
```

where `g` is a generator. Each of the arguments (a1 ... aN) can either be an immediate value, or a function, `f`, with signature:

```
T f(Unused, Context)
```

where `T`, the function's return value, is compatible with the argument type expected and `Context` is the generators's Context type (The first argument is `unused` to make the `Context` the second argument. This is done for uniformity with Semantic Actions).

Character Encoding Namespace

Some generators need to know which character set a `char` or `wchar_t` is operating on. For example, the `alnum` generator works differently with ISO8859.1 and ASCII encodings. Where necessary, Spirit encodes (tags) the generator with the character set.

We have a namespace for each character set Spirit will be supporting. That includes `ascii`, `iso8859_1`, `standard` and `standard_wide` (and in the future, `unicode`). In each of the character encoding namespaces, we place tagged versions of generators such as `alnum`, `space` etc.

Example:

```
using boost::spirit::ascii::space; // use the ASCII space generator
```

Namespaces:

- boost::spirit::ascii
- boost::spirit::iso8859_1
- boost::spirit::standard
- boost::spirit::standard_wide

For ease of use, the components in this namespaces are also brought into the karma sub-namespaces with the same names:

- boost::spirit::karma::ascii
- boost::spirit::karma::iso8859_1
- boost::spirit::karma::standard
- boost::spirit::karma::standard_wide

Examples

All sections in the reference present some real world examples. The examples use a common test harness to keep the example code as minimal and direct to the point as possible. The test harness is presented below.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

The used output iterator:

```
typedef std::back_insert_iterator<std::string> output_iterator_type;
```

Our test functions:

This one tests the generators without attributes.

```
template <typename G>
void test_generator(char const* expected, G const& g)
{
    std::string s;
    std::back_insert_iterator<std::string> out(s);
    if (boost::spirit::karma::generate(out, g) && s == expected)
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}
```

These test the generators with one or more user supplied attributes.

```
template <typename G, typename T>
void test_generator_attr(char const* expected, G const& g, T const& attr)
{
    std::string s;
    std::back_insert_iterator<std::string> out(s);
    if (boost::spirit::karma::generate(out, g, attr) && s == expected)
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}
```

```
template <typename G, typename T1, typename T2>
void test_generator_attr(char const* expected, G const& g, T1 const& attr1,
    T2 const& attr2)
{
    std::string s;
    std::back_insert_iterator<std::string> out(s);
    if (boost::spirit::karma::generate(out, g, attr1, attr2) && s == expected)
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}
```

This tests the generators with one attribute and while using delimited output.

```
template <typename G, typename Delimiter, typename T>
void test_generator_attr_delim(char const* expected, G const& g, Delimiter const& d, T const& attr)
{
    std::string s;
    std::back_insert_iterator<std::string> out(s);
    if (boost::spirit::karma::generate_delimited(out, g, d, attr) && s == expected)
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}
```

The examples of the binary generators use one or more of the following tests.

```
template <typename G>
void test_binary_generator(char const* expected, std::size_t size, G const& g)
{
    std::string s;
    std::back_insert_iterator<std::string> out(s);
    if (boost::spirit::karma::generate(out, g) && !std::memcmp(s.c_str(), expected, size))
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}
```

```
template <typename G, typename T>
void test_binary_generator_attr(char const* expected, std::size_t size, G const& g, T const& attr)
{
    std::string s;
    std::back_insert_iterator<std::string> out(s);
   if (boost::spirit::karma::generate(out, g, attr) && !std::memcmp(s.c_str(), expected, size))
        std::cout << "ok" << std::endl;
    else
        std::cout << "fail" << std::endl;
}
```

Models

Predefined models include:

- any literal string, e.g. "Hello, World",
- a pointer/reference to a null-terminated array of characters
- a `std::basic_string<Char>`

The namespace `boost::spirit::traits` is open for users to provide their own specializations. The customization points implemented by *Spirit.Karma* usable to customize the behavior of generators are described in the section Customization of Attribute Handling.

Generate API

Iterator Based Generate API

Description

The library provides a couple of free functions to make generating a snap. These generator functions have two forms. The first form, `generate`, concatenates the output generated by the involved components without inserting any output in between. The second `generate_delimited` intersperses the output generated by the involved components using the given delimiter generator. Both versions can take in attributes by (constant) reference that hold the attribute values to output.

Header

```
// forwards to <boost/spirit/home/karma/generate.hpp>
#include <boost/spirit/include/karma_generate.hpp>
```

For variadic attributes:

```
// forwards to <boost/spirit/home/karma/generate_attr.hpp>
#include <boost/spirit/include/karma_generate_attr.hpp>
```

The variadic attributes version of the API allows one or more attributes to be passed into the `generate` functions. The functions taking two or more attributes are usable when the generator expression is a Sequence (<<) only. In this case each of the attributes passed have to match the corresponding part of the sequence.

Also, see Include Structure.

Namespace

Name
`boost::spirit::karma::generate`
`boost::spirit::karma::generate_delimited`
`boost::spirit::karma::delimit_flag::predelimit`
`boost::spirit::karma::delimit_flag::dont_predelimit`

Synopsis

```
template <typename OutputIterator, typename Expr>
inline bool
generate(
    OutputIterator& sink
  , Expr const& expr);

template <typename OutputIterator, typename Expr
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline bool
generate(
    OutputIterator& sink
  , Expr const& expr
  , Attr1 const& attr1, Attr2 const& attr2, ..., AttrN const& attrN);

template <typename OutputIterator, typename Expr, typename Delimiter>
inline bool
generate_delimited(
    OutputIterator& sink
  , Expr const& expr
  , Delimiter const& delimiter
  , BOOST_SCOPED_ENUM(delimit_flag) pre_delimit = delimit_flag::dont_predelimit);

template <typename OutputIterator, typename Expr, typename Delimiter
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline bool
generate_delimited(
    OutputIterator& sink
  , Expr const& expr
  , Delimiter const& delimiter
  , Attr1 const& attr1, Attr2 const& attr2, ..., AttrN const& attrN);

template <typename OutputIterator, typename Expr, typename Delimiter
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline bool
generate_delimited(
    OutputIterator& sink
  , Expr const& expr
  , Delimiter const& delimiter
  , BOOST_SCOPED_ENUM(delimit_flag) pre_delimit
  , Attr1 const& attr1, Attr2 const& attr2, ..., AttrN const& attrN);
```

All functions above return `true` if none of the involved generator components failed, and `false` otherwise. If during the process of the output generation the underlying output stream reports an error, the return value will be `false` as well.

The maximum number of supported arguments is limited by the preprocessor constant `SPIRIT_ARGUMENTS_LIMIT`. This constant defaults to the value defined by the preprocessor constant `PHOENIX_LIMIT` (which in turn defaults to `10`).

Note

The variadic function with two or more attributes internally combine (constant) references to all passed attributes into a `fusion::vector` and forward this as a combined attribute to the corresponding function taking one attribute.

The `generate_delimited` functions not taking an explicit `delimit_flag` as one of their arguments don't invoke the passed delimiter before starting to generate output from the generator expression. This can be enabled by using the other version of that function while passing `delimit_flag::predelimit` to the corresponding argument.

Template parameters

Parameter	Description
`OutputIterator`	`OutputIterator` receiving the generated output.
`Expr`	An expression that can be converted to a Karma generator.
`Delimiter`	Generator used to delimit the output of the expression components.
`Attr1`, `Attr2`, ..., `AttrN`	One or more attributes.

Stream Based Generate API

Description

The library provides a couple of Standard IO Manipulators allowing to integrate *Spirit.Karma* output generation facilities with Standard output streams. These generator manipulators have two forms. The first form, `format`, concatenates the output generated by the involved components without inserting any output in between. The second, `format_delimited`, intersperses the output generated by the involved components using the given delimiter generator. Both versions can take in attributes by (constant) reference that hold the attribute values to output.

Header

```
// forwards to <boost/spirit/home/karma/stream/format_manip.hpp>
#include <boost/spirit/include/karma_format.hpp>
```

For variadic attributes:

```
// forwards to <boost/spirit/home/karma/stream/format_manip_attr.hpp>
#include <boost/spirit/include/karma_format_attr.hpp>
```

The variadic attributes version of the API allows one or more attributes to be passed into the `format` manipulators. The manipulators taking two or more attributes are usable when the generator expression is a Sequence (<<) only. In this case each of the attributes passed have to match the corresponding part of the sequence.

Also, see Include Structure.

Namespace

Name
`boost::spirit::karma::format`
`boost::spirit::karma::format_delimited`
`boost::spirit::karma::delimit_flag::predelimit`
`boost::spirit::karma::delimit_flag::dont_predelimit`

Synopsis

```
template <typename Expr>
inline <unspecified>
format(
    Expr const& xpr);

template <typename Expr
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline <unspecified>
format(
    Expr const& xpr
  , Attr1 const& attr1, Attr2 const& attr2, ..., AttrN const& attrN);

template <typename Expr, typename Delimiter>
inline <unspecified>
format_delimited(
    Expr const& expr
  , Delimiter const& d
  , BOOST_SCOPED_ENUM(delimit_flag) pre_delimit = delimit_flag::dont_predelimit);

template <typename Expr, typename Delimiter
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline <unspecified>
format_delimited(
    Expr const& expr
  , Delimiter const& d
  , Attr1 const& attr1, Attr2 const& attr2, ..., AttrN const& attrN);

template <typename Expr, typename Delimiter
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline <unspecified>
format_delimited(
    Expr const& expr
  , Delimiter const& d
  , BOOST_SCOPED_ENUM(delimit_flag) pre_delimit
  , Attr1 const& attr1, Attr2 const& attr2, ..., AttrN const& attrN);
```

All functions above return a standard IO stream manipulator instance (see Manipulators), which when streamed to an output stream will result in generating the output as emitted by the embedded *Spirit.Karma* generator expression. Any error occuring during the invocation of the *Spirit.Karma* generators will be reflected in the streams status flag (`std::ios_base::failbit` will be set).

The maximum number of supported arguments is limited by the preprocessor constant `SPIRIT_ARGUMENTS_LIMIT`. This constant defaults to the value defined by the preprocessor constant `PHOENIX_LIMIT` (which in turn defaults to `10`).

Note

The variadic manipulators with two or more attributes internally combine (constant) references to all passed attributes into a `fusion::vector` and forward this as a combined attribute to the corresponding manipulator taking one attribute.

The `format_delimited` manipulators not taking an explicit `delimit_flag` as one of their arguments don't invoke the passed delimiter before starting to generate output from the generator expression. This can be enabled by using the other version of that manipulator while passing `delimit_flag::predelimit` to the corresponding argument.

Template parameters

Parameter	Description
`Expr`	An expression that can be converted to a Karma generator.
`Delimiter`	Generator used to delimit the output of the expression components.
`Attr1`, `Attr2`, ..., `AttrN`	One or more attributes.

Action

Description

Semantic actions may be attached to any point in the grammar specification. They allow to call a function or function object in order to provide the value to be output by the generator the semantic action is attached to. Semantic actions are associated with a generator using the syntax `g[]`, where `g` is an arbitrary generator expression.

Header

```
// forwards to <boost/spirit/home/karma/action.hpp>
#include <boost/spirit/include/karma_action.hpp>
```

Also, see Include Structure.

Model of

`UnaryGenerator`

Notation

`a`, `g` — Instances of a generator, `G`

`A` — Attribute type exposed by a generator, `a`

`fa` — A (semantic action) function with signature `void(Attrib&, Context&, bool&)`. The third parameter is a boolean flag that can be set to false to force the generator to fail. Both `Context` and the boolean flag are optional. For more information see below.

`Attrib` — The attribute to be used to generate output from.

`Context` — The type of the generator execution context. For more information see below.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`g[fa]`	Call semantic action, `fa` *before* invoking `g`. The function or function object `fa` is expected to provide the value to generate output from to the generator `g`.

The possible signatures for functions to be used as semantic actions are:

```
template <typename Attrib>
void fa(Attrib& attr);

template <typename Attrib, typename Context>
void fa(Attrib& attr, Context& context);

template <typename Attrib, typename Context>
void fa(Attrib& attr, Context& context, bool& pass);
```

The function or function object is expected to return the value to generate output from by assigning it to the first parameter, `attr`. Here `Attrib` is the attribute type of the generator the semantic action is attached to.

The type `Context` is the type of the generator execution context. This type is unspecified and depends on the context the generator is invoked in. The value `context` is used by semantic actions written using Phoenix to access various context dependent attributes and values. For more information about Phoenix placeholder expressions usable in semantic actions see `Nonterminal`.

The third parameter, `pass`, can be used by the semantic action to force the associated generator to fail. If pass is set to `false` the action generator will immediately return `false` as well, while not invoking `g` and not generating any output.

Attributes

Expression	Attribute
`a[fa]`	`a: A --> a[fa]: A`

Complexity

The complexity of the action generator is defined by the complexity of the generator the semantic action is attached to and the complexity of the function or function object used as the semantic action.

Important

Please note that the use of semantic actions in *Spirit.Karma* generally forces the library to create a *copy* of the attribute, which might be a costly operation. Always consider using other means of associating a value with a particular generator first.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::int_;
using boost::spirit::karma::string;
using boost::spirit::karma::_1;
using boost::phoenix::ref;
using boost::phoenix::val;
```

Some examples:

```
int i = 42;
test_generator("42", int_[_1 = ref(i)]);
test_generator("abc", string[_1 = val("abc")]);
```

More examples for semantic actions can be found here: Examples of Semantic Actions.

Auxiliary

This module includes different auxiliary generators not fitting into any of the other categories. It includes the `attr_cast`, `eol`, `eps`, and `lazy` generators.

Module Header

```
// forwards to <boost/spirit/home/karma/auxiliary.hpp>
#include <boost/spirit/include/karma_auxiliary.hpp>
```

Also, see Include Structure.

Attribute Transformation Pseudo Generator (`attr_cast`)

Description

The `attr_cast<Exposed, Transformed>()` component invokes the embedded generator while supplying an attribute of type `Transformed`. The supplied attribute gets created from the original attribute (of type `Exposed`) passed to this component using the customization point `transform_attribute`.

Header

```
// forwards to <boost/spirit/home/karma/auxiliary/attr_cast.hpp>
#include <boost/spirit/include/karma_attr_cast.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::attr_cast // alias: boost::spirit::karma::attr_cast`

Synopsis

```
template <Exposed, Transformed>
<unspecified> attr_cast(<unspecified>);
```

Template parameters

Parameter	Description	Default
`Exposed`	The type of the attribute supplied to the `attr_cast`.	`unused_type`
`Transformed`	The type of the attribute expected by the embedded generator `g`.	`unused_type`

The `attr_cast` is a function template. It is possible to invoke it using the following schemes:

```
attr_cast(g)
attr_cast<Exposed>(g)
attr_cast<Exposed, Transformed>(g)
```

depending on which of the attribute types can be deduced properly if not explicitly specified.

Model of

`UnaryGenerator`

Notation

`g` A generator object.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`attr_cast(g)`	Create a component invoking the generator `g` while passing an attribute of the type as normally expected by `g`. The type of the supplied attribute will be transformed to the type `g` exposes as its attribute type (by using the attribute customization point `transform_attribute`). This generator does not fail unless `g` fails.
`attr_cast<Exposed>(g)`	Create a component invoking the generator `g` while passing an attribute of the type as normally expected by `g`. The supplied attribute is expected to be of the type `Exposed`, it will be transformed to the type `g` exposes as its attribute type (using the attribute customization point `transform_attribute`). This generator does not fail unless `g` fails.
`attr_cast<Exposed, Transformed>(g)`	Create a component invoking the generator `g` while passing an attribute of type `Transformed`. The supplied attribute is expected to be of the type `Exposed`, it will be transformed to the type `Transformed` (using the attribute customization point `transform_attribute`). This generator does not fail unless `g` fails.

Attributes

Expression	Attribute
`attr_cast(g)`	`g: A --> attr_cast(g): A`
`attr_cast<Exposed>(g)`	`g: A --> attr_cast<Exposed>(g): Exposed`
`attr_cast<Exposed, Transformed>(g)`	`g: A --> attr_cast<Exposed, Transformed>(g): Exposed`

Complexity

The complexity of this component is fully defined by the complexity of the embedded generator `g`.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::int_;
```

The example references data structure `int_data` which needs a specialization of the customization point `transform_attribute`:

```
// this is just a test structure we want to use in place of an int
struct int_data
{
    int i;
};

// we provide a custom attribute transformation to allow its use as an int
namespace boost { namespace spirit { namespace traits
{
    template <>
    struct transform_attribute<int_data const, int>
    {
        typedef int type;
        static int pre(int_data const& d) { return d.i; }
    };
}}}
```

Now we use the `attr_cast` pseudo generator to invoke the attribute transformation:

```
int_data d = { 1 };
test_generator_attr("1", boost::spirit::karma::attr_cast(int_), d);
```

End of Line (`eol`)

Description

The `eol` component generates a single newline character. It is equivalent to `lit('\n')` or simply '\n' (please see the `char_` generator module for more details).

Header

```
// forwards to <boost/spirit/home/karma/auxiliary/eol.hpp>
#include <boost/spirit/include/karma_eol.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::eol // alias: boost::spirit::karma::eol`

Model of

`PrimitiveGenerator`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Semantics
`eol`	Create a component generating a single end of line character in the output. This generator never fails (unless the underlying output stream reports an error).

Attributes

Expression	Attribute
`eol`	`unused`

Complexity

O(1)

The complexity is constant as a single character is generated in the output.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::eol;
```

Basic usage of the `eol` generator:

```
test_generator("\n", eol);
test_generator("abc\n", "abc" << eol);
```

Epsilon (eps)

The family of `eps` components allows to create pseudo generators generating an empty string. This feature is sometimes useful either to force a generator to fail or to succeed or to insert semantic actions into the generation process.

Description

The Epsilon (`eps`) is a multi-purpose generator that emits a yero length string.

Simple Form

In its simplest form, `eps` creates a component generating an empty string while always succeeding:

```
eps       // always emits a zero-length string
```

This form is usually used to trigger a semantic action unconditionally. For example, it is useful in triggering error messages when a set of alternatives fail:

```
r = a | b | c | eps[error()]; // Call error if a, b, and c fail to generate
```

Semantic Predicate

The `eps(b)` component generates an empty string as well, but succeeds only if `b` is `true` and fails otherwise. It's lazy variant `eps(fb)` is equivalent to `eps(b)` except it evaluates the supplied function `fb` at generate time, while using the return value as the criteria to succeed.

Semantic predicates allow you to attach a conditional function anywhere in the grammar. In this role, the epsilon takes a Lazy Argument that returns `true` or `false`. The Lazy Argument is typically a test that is called to resolve ambiguity in the grammar. A generator failure will be reported when the Lazy Argument result evaluates to `false`. Otherwise an empty string will be emitted. The general form is:

```
eps_p(fb) << rest;
```

The Lazy Argument `fb` is called to do a semantic test. If the test returns true, `rest` will be evaluated. Otherwise, the production will return early without ever touching rest.

Header

```
// forwards to <boost/spirit/home/karma/auxiliary/eps.hpp>
#include <boost/spirit/include/karma_eps.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::eps // alias: boost::spirit::karma::eps`

Model of

`PrimitiveGenerator`

Notation

`b` A boolean value.

`fb` A Lazy Argument that evaluates to a boolean value.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Semantics
`eps`	Creates a component generating an empty string. Succeeds always.
`eps(b)`	Creates a component generating an empty string. Succeeds if `b` is `true` (unless the underlying output stream reports an error).
`eps(fb)`	Creates a component generating an empty string. Succeeds if `fb` returns `true` at generate time (unless the underlying output stream reports an error).

Attributes

Expression	Attribute
`eps`	`unused`
`eps(b)`	`unused`
`eps(fb)`	`unused`

Complexity

O(1)

The complexity is constant as no output is generated.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::eps;
using boost::phoenix::val;
```

Basic usage of the `eps` generator:

```
test_generator("abc", eps[std::cout << val("starting eps example")] << "abc");
test_generator("abc", eps(true) << "abc");
test_generator("", eps(false) << "abc");      // fails as eps expression is 'false'
```

Lazy (`lazy`)

Description

The familiy of `lazy` components allows to use a dynamically returned generator component for output generation. It calls the provided function or function object at generate time using its return value as the actual generator to produce the output.

Header

```
// forwards to <boost/spirit/home/karma/auxiliary/lazy.hpp>
#include <boost/spirit/include/karma_lazy.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lazy // alias: boost::spirit::karma::lazy`

Model of

`Generator`

Notation

`fg` A function or function object that evaluates to a generator object (an object exposing the `Generator`). This function will be invoked at generate time.

The signature of `fg` is expected to be

```
G f(Unused, Context)
```

where `G`, the function's return value, is the type of the generator to be invoked, and `Context` is the generators's Context type (The first argument is `unused` to make the `Context` the second argument. This is done for uniformity with Semantic Actions).

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `Generator`.

Expression	Semantics
`fg`	The Boost.Phoenix function object `fg` will be invoked at generate time. It is expected to return a generator instance. This generator is then invoked in order to generate the output. This generator will succeed as long as the invoked generated succeeds as well (unless the underlying output stream reports an error).
`lazy(fg)`	The function or function object will be invoked at generate time. It is expected to return a generator instance (note this version of `lazy` does not require `fg` to be a Boost.Phoenix function object). This generator is then invoked in order to generate the output. This generator will succeed as long as the invoked generated succeeds as well (except if the underlying output stream reports an error).

Attributes

Expression	Attribute
`fg`	The attribute type `G` as exposed by the generator `g` returned from `fg`.
`lazy(fg)`	The attribute type `G` as exposed by the generator `g` returned from `fg`.

Complexity

The complexity of the `lazy` component is determined by the complexity of the generator returned from `fg`.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
namespace karma = boost::spirit::karma;
using boost::spirit::karma::_1;
using boost::spirit::ascii::string;
using boost::phoenix::val;
```

Basic usage of the `lazy` generator:

```
test_generator_attr("abc", karma::lazy(val(string)), "abc");
test_generator("abc", karma::lazy(val(string))[_1 = "abc"]);
```

Binary

This module includes different generators allowing to output binary data. It includes generators for default, little, and big endian binary output and a `pad` generator allowing to control padding of the generated output stream.

Module Header

```
// forwards to <boost/spirit/home/karma/binary.hpp>
#include <boost/spirit/include/karma_binary.hpp>
```

Also, see Include Structure.

Binary Native Endianness Generators

Description

The binary native endianness generators described in this section are used to emit binary byte streams layed out conforming to the native endianess (byte order) of the target architecture.

Header

```
// forwards to <boost/spirit/home/karma/binary.hpp>
#include <boost/spirit/include/karma_binary.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::byte_ // alias: boost::spirit::karma::byte_`
`boost::spirit::word // alias: boost::spirit::karma::word`
`boost::spirit::dword // alias: boost::spirit::karma::dword`
`boost::spirit::qword // alias: boost::spirit::karma::qword`

Note

The generators `qword` and `qword(qw)` are only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `unsigned long long` (64 bit) integer types).

Model of

`PrimitiveGenerator`

Notation

`b` A single byte (8 bit binary value) or a Lazy Argument that evaluates to a single byte

`w` A 16 bit binary value or a Lazy Argument that evaluates to a 16 bit binary value. This value is always interpreted using native endianness.

`dw` A 32 bit binary value or a Lazy Argument that evaluates to a 32 bit binary value. This value is always interpreted using native endianness.

`qw` A 64 bit binary value or a Lazy Argument that evaluates to a 64 bit binary value. This value is always interpreted using native endianness.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Description
`byte_`	Output the binary representation of the least significant byte of the mandatory attribute. This generator never fails (unless the underlying output stream reports an error).
`word`	Output the binary representation of the least significant 16 bits of the mandatory attribute in native endian representation. This generator never fails (unless the underlying output stream reports an error).
`dword`	Output the binary representation of the least significant 32 bits of the mandatory attribute in native endian representation. This generator never fails (unless the underlying output stream reports an error).
`qword`	Output the binary representation of the least significant 64 bits of the mandatory attribute in native endian representation. This generator never fails (unless the underlying output stream reports an error).
`byte_(b)`	Output the binary representation of the least significant byte of the immediate parameter. This generator never fails (unless the underlying output stream reports an error).
`word(w)`	Output the binary representation of the least significant 16 bits of the immediate parameter in native endian representation. This generator never fails (unless the underlying output stream reports an error).
`dword(dw)`	Output the binary representation of the least significant 32 bits of the immediate parameter in native endian representation. This generator never fails (unless the underlying output stream reports an error).
`qword(qw)`	Output the binary representation of the least significant 64 bits of the immediate parameter in native endian representation. This generator never fails (unless the underlying output stream reports an error).

Attributes

Expression	Attribute
`byte_`	`boost::uint_least8_t`, attribute is mandatory (otherwise compilation will fail)
`word`	`boost::uint_least16_t`, attribute is mandatory (otherwise compilation will fail)
`dword`	`boost::uint_least32_t`, attribute is mandatory (otherwise compilation will fail)
`qword`	`boost::uint_least64_t`, attribute is mandatory (otherwise compilation will fail)
`byte_(b)`	`unused`
`word(w)`	`unused`
`dword(dw)`	`unused`
`qword(qw)`	`unused`

Note

In addition to their usual attribute of type `Attrib` all listed generators accept an instance of a `boost::optional<Attrib>` as well. If the `boost::optional<>` is initialized (holds a value) the generators behave as if their attribute was an instance of `Attrib` and emit the value stored in the `boost::optional<>`. Otherwise the generators will fail.

Complexity

O(N), where N is the number of bytes emitted by the binary generator

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::byte_;
using boost::spirit::karma::word;
using boost::spirit::karma::dword;
using boost::spirit::karma::qword;
```

Basic usage of the native binary generators with some results for little endian platforms:

```
test_binary_generator("\x01", 1, byte_(0x01));
test_binary_generator("\x01\x02", 2, word(0x0201));
test_binary_generator("\x01\x02\x03\x04", 4, dword(0x04030201));
test_binary_generator("\x01\x02\x03\x04\x05\x06\x07\x08", 8, qword(0x0807060504030201LL));

test_binary_generator_attr("\x01", 1, byte_, 0x01);
test_binary_generator_attr("\x01\x02", 2, word, 0x0201);
test_binary_generator_attr("\x01\x02\x03\x04", 4, dword, 0x04030201);
test_binary_generator_attr("\x01\x02\x03\x04\x05\x06\x07\x08", 8, qword, 0x0807060504030201LL);
```

Basic usage of the native binary generators with some results for big endian platforms:

```
test_binary_generator("\x01", 1, byte_(0x01));
test_binary_generator("\x02\x01", 2, word(0x0201));
test_binary_generator("\x04\x03\x02\x01", 4, dword(0x04030201));
test_binary_generator("\x08\x07\x06\x05\x04\x03\x02\x01", 8, qword(0x0807060504030201LL));

test_binary_generator_attr("\x01", 1, byte_, 0x01);
test_binary_generator_attr("\x02\x01", 2, word, 0x0201);
test_binary_generator_attr("\x04\x03\x02\x01", 4, dword, 0x04030201);
test_binary_generator_attr("\x08\x07\x06\x05\x04\x03\x02\x01", 8, qword, 0x0807060504030201LL);
```

Binary Little Endianness Generators

Description

The little native endianness generators described in this section are used to emit binary byte streams layed out conforming to the little endianess byte order.

Header

```
// forwards to <boost/spirit/home/karma/binary.hpp>
#include <boost/spirit/include/karma_binary.hpp>
```

Also, see Include Structure.

Namespace

Name
boost::spirit::little_word // alias: boost::spirit::karma::little_word
boost::spirit::little_dword // alias: boost::spirit::karma::little_dword
boost::spirit::little_qword // alias: boost::spirit::karma::little_qword

Note

The generators `little_qword` and `little_qword(qw)` are only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `unsigned long long` (64 bit) integer types).

Model of

`PrimitiveGenerator`

Notation

`w` A 16 bit binary value or a Lazy Argument that evaluates to a 16 bit binary value. This value is always interpreted using native endianness.

`dw` A 32 bit binary value or a Lazy Argument that evaluates to a 32 bit binary value. This value is always interpreted using native endianness.

`qw` A 64 bit binary value or a Lazy Argument that evaluates to a 64 bit binary value. This value is always interpreted using native endianness.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Description
`little_word`	Output the binary representation of the least significant 16 bits of the mandatory attribute in little endian representation. This generator never fails (unless the underlying output stream reports an error).
`little_dword`	Output the binary representation of the least significant 32 bits of the mandatory attribute in little endian representation. This generator never fails (unless the underlying output stream reports an error).
`little_qword`	Output the binary representation of the least significant 64 bits of the mandatory attribute in little endian representation. This generator never fails (unless the underlying output stream reports an error).
`little_word(w)`	Output the binary representation of the least significant 16 bits of the immediate parameter in little endian representation. This generator never fails (unless the underlying output stream reports an error).
`little_dword(dw)`	Output the binary representation of the least significant 32 bits of the immediate parameter in little endian representation. This generator never fails (unless the underlying output stream reports an error).
`little_qword(qw)`	Output the binary representation of the least significant 64 bits of the immediate parameter in little endian representation. This generator never fails (unless the underlying output stream reports an error).

Attributes

Expression	Attribute
`little_word`	`boost::uint_least16_t`, attribute is mandatory (otherwise compilation will fail)
`little_dword`	`boost::uint_least32_t`, attribute is mandatory (otherwise compilation will fail)
`little_qword`	`boost::uint_least64_t`, attribute is mandatory (otherwise compilation will fail)
`little_word(w)`	`unused`
`little_dword(dw)`	`unused`
`little_qword(qw)`	`unused`

Complexity

O(N), where N is the number of bytes emitted by the binary generator

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::little_word;
using boost::spirit::karma::little_dword;
using boost::spirit::karma::little_qword;
```

Basic usage of the little binary generators:

```
test_binary_generator("\x01\x02", 2, little_word(0x0201));
test_binary_generator("\x01\x02\x03\x04", 4, little_dword(0x04030201));
test_binary_generator("\x01\x02\x03\x04\x05\x06\x07\x08", 8, little_qword(0x0807060504030201LL));

test_binary_generator_attr("\x01\x02", 2, little_word, 0x0201);
test_binary_generator_attr("\x01\x02\x03\x04", 4, little_dword, 0x04030201);
test_binary_generator_at↵
tr("\x01\x02\x03\x04\x05\x06\x07\x08", 8, little_qword, 0x0807060504030201LL);
```

Binary Big Endianness Generators

Description

The big native endianness generators described in this section are used to emit binary byte streams layed out conforming to the big endianess byte order.

Header

```
// forwards to <boost/spirit/home/karma/binary.hpp>
#include <boost/spirit/include/karma_binary.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::big_word // alias: boost::spirit::karma::big_word`
`boost::spirit::big_dword // alias: boost::spirit::karma::big_dword`
`boost::spirit::big_qword // alias: boost::spirit::karma::big_qword`

Note

The generators `big_qword` and `big_qword(qw)` are only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `unsigned long long` (64 bit) integer types).

Model of

`PrimitiveGenerator`

Notation

`w` A 16 bit binary value or a Lazy Argument that evaluates to a 16 bit binary value. This value is always interpreted using native endianness.

`dw` A 32 bit binary value or a Lazy Argument that evaluates to a 32 bit binary value. This value is always interpreted using native endianness.

`qw` A 64 bit binary value or a Lazy Argument that evaluates to a 64 bit binary value. This value is always interpreted using native endianness.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Description
`big_word`	Output the binary representation of the least significant 16 bits of the mandatory attribute in big endian representation. This generator never fails (unless the underlying output stream reports an error).
`big_dword`	Output the binary representation of the least significant 32 bits of the mandatory attribute in big endian representation. This generator never fails (unless the underlying output stream reports an error).
`big_qword`	Output the binary representation of the least significant 64 bits of the mandatory attribute in big endian representation. This generator never fails (unless the underlying output stream reports an error).
`big_word(w)`	Output the binary representation of the least significant 16 bits of the immediate parameter in big endian representation. This generator never fails (unless the underlying output stream reports an error).
`big_dword(dw)`	Output the binary representation of the least significant 32 bits of the immediate parameter in big endian representation. This generator never fails (unless the underlying output stream reports an error).
`big_qword(qw)`	Output the binary representation of the least significant 64 bits of the immediate parameter in big endian representation. This generator never fails (unless the underlying output stream reports an error).

Attributes

Expression	Attribute
`big_word`	`boost::uint_least16_t`, attribute is mandatory (otherwise compilation will fail)
`big_dword`	`boost::uint_least32_t`, attribute is mandatory (otherwise compilation will fail)
`big_qword`	`boost::uint_least64_t`, attribute is mandatory (otherwise compilation will fail)
`big_word(w)`	`unused`
`big_dword(dw)`	`unused`
`big_qword(qw)`	`unused`

Complexity

O(N), where N is the number of bytes emitted by the binary generator

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::big_word;
using boost::spirit::karma::big_dword;
using boost::spirit::karma::big_qword;
```

Basic usage of the big binary generators:

```
test_binary_generator("\x02\x01", 2, big_word(0x0201));
test_binary_generator("\x04\x03\x02\x01", 4, big_dword(0x04030201));
test_binary_generator("\x08\x07\x06\x05\x04\x03\x02\x01", 8, big_qword(0x0807060504030201LL));

test_binary_generator_attr("\x02\x01", 2, big_word, 0x0201);
test_binary_generator_attr("\x04\x03\x02\x01", 4, big_dword, 0x04030201);
test_binary_generator_attr("\x08\x07\x06\x05\x04\x03\x02\x01", 8, big_qword, 0x0807060504030201LL);
```

Char

This module includes different character oriented generators allowing to output single characters. Currently, it includes literal chars (e.g. `'x'`, `L'x'`), `char_` (single characters, ranges and character sets) and the encoding specific character classifiers (`alnum`, `alpha`, `digit`, `xdigit`, etc.).

Module Header

```
// forwards to <boost/spirit/home/karma/char.hpp>
#include <boost/spirit/include/karma_char.hpp>
```

Also, see Include Structure.

Character Generators (`char_`, `lit`)

Description

The character generators described in this section are:

The `char_` generator emits single characters. The `char_` generator has an associated Character Encoding Namespace. This is needed when doing basic operations such as forcing lower or upper case and dealing with character ranges.

There are various forms of `char_`.

char_

The no argument form of `char_` emits any character in the associated Character Encoding Namespace.

```
char_               // emits any character as supplied by the attribute
```

char_(ch)

The single argument form of `char_` (with a character argument) emits the supplied character.

```
char_('x')          // emits 'x'
char_(L'x')         // emits L'x'
char_(x)            // emits x (a char)
```

char_(first, last)

`char_` with two arguments, emits any character from a range of characters as supplied by the attribute.

```
char_('a','z')      // alphabetic characters
char_(L'0',L'9')    // digits
```

A range of characters is created from a low-high character pair. Such a generator emits a single character that is in the range, including both endpoints. Note, the first character must be *before* the second, according to the underlying Character Encoding Namespace.

Character mapping is inherently platform dependent. It is not guaranteed in the standard for example that `'A' < 'Z'`, that is why in Spirit2, we purposely attach a specific Character Encoding Namespace (such as ASCII, ISO-8859-1) to the `char_` generator to eliminate such ambiguities.

Note

Sparse bit vectors

To accomodate 16/32 and 64 bit characters, the char-set statically switches from a `std::bitset` implementation when the character type is not greater than 8 bits, to a sparse bit/boolean set which uses a sorted vector of disjoint ranges (`range_run`). The set is constructed from ranges such that adjacent or overlapping ranges are coalesced.

`range_runs` are very space-economical in situations where there are lots of ranges and a few individual disjoint values. Searching is O(log n) where n is the number of ranges.

char_(def)

Lastly, when given a string (a plain C string, a `std::basic_string`, etc.), the string is regarded as a char-set definition string following a syntax that resembles posix style regular expression character sets (except that double quotes delimit the set elements instead of square brackets and there is no special negation ^ character). Examples:

```
char_("a-zA-Z")     // alphabetic characters
char_("0-9a-fA-F")  // hexadecimal characters
char_("actgACTG")   // DNA identifiers
char_("\x7f\x7e")   // Hexadecimal 0x7F and 0x7E
```

These generators emit any character from a range of characters as supplied by the attribute.

lit(ch)

`lit`, when passed a single character, behaves like the single argument `char_` except that `lit` does not consume an attribute. A plain `char` or `wchar_t` is equivalent to a `lit`.

Note

`lit` is reused by the String Generators, the char generators, and the Numeric Generators (see signed integer, unsigned integer, and real number generators). In general, a char generator is created when you pass in a character, a string generator is created when you pass in a string, and a numeric generator is created when you use a numeric literal. The exception is when you pass a single element literal string, e.g. `lit("x")`. In this case, we optimize this to create a char generator instead of a string generator.

Examples:

```
'x'
lit('x')
lit(L'x')
lit(c)      // c is a char
```

Header

```
// forwards to <boost/spirit/home/karma/char/char.hpp>
#include <boost/spirit/include/karma_char_.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lit // alias: boost::spirit::karma::lit`
`ns::char_`

In the table above, `ns` represents a Character Encoding Namespace.

Model of

`PrimitiveGenerator`

Notation

`ch`, `ch1`, `ch2`	Character-class specific character (See Character Class Types), or a Lazy Argument that evaluates to a character-class specific character value
`cs`	Character-set specifier string (See Character Class Types), or a Lazy Argument that evaluates to a character-set specifier string, or a pointer/reference to a null-terminated array of characters. This string specifies a char-set definition string following a syntax that resembles posix style regular expression character sets (except the square brackets and the negation `^` character).
`ns`	A Character Encoding Namespace.
`cg`	A char generator, a char range generator, or a char set generator.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Description
`ch`	Generate the character literal `ch`. This generator never fails (unless the underlying output stream reports an error).
`lit(ch)`	Generate the character literal `ch`. This generator never fails (unless the underlying output stream reports an error).
`ns::char_`	Generate the character provided by a mandatory attribute interpreted in the character set defined by `ns`. This generator never fails (unless the underlying output stream reports an error).
`ns::char_(ch)`	Generate the character `ch` as provided by the immediate literal value the generator is initialized from. If this generator has an associated attribute it succeeds only as long as the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.
`ns::char_("c")`	Generate the character `c` as provided by the immediate literal value the generator is initialized from. If this generator has an associated attribute it succeeds only as long as the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.
`ns::char_(ch1, ch2)`	Generate the character provided by a mandatory attribute interpreted in the character set defined by `ns`. The generator succeeds as long as the attribute belongs to the character range `[ch1, ch2]` (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.
`ns::char_(cs)`	Generate the character provided by a mandatory attribute interpreted in the character set defined by `ns`. The generator succeeds as long as the attribute belongs to the character set `cs` (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.
`~cg`	Negate `cg`. The result is a negated char generator that inverts the test condition of the character generator it is attached to.

A character `ch` is assumed to belong to the character range defined by `ns::char_(ch1, ch2)` if its character value (binary representation) interpreted in the character set defined by `ns` is not smaller than the character value of `ch1` and not larger then the character value of `ch2` (i.e. `ch1 <= ch <= ch2`).

The `charset` parameter passed to `ns::char_(charset)` must be a string containing more than one character. Every single character in this string is assumed to belong to the character set defined by this expression. An exception to this is the `'-'` character which has a special meaning if it is not specified as the first and not the last character in `charset`. If the `'-'` is used in between to characters it is interpreted as spanning a character range. A character `ch` is considered to belong to the defined character set `charset` if it matches one of the characters as specified by the string parameter described above. For example

Example	Description
`char_("abc")`	'a', 'b', and 'c'
`char_("a-z")`	all characters (and including) from 'a' to 'z'
`char_("a-zA-Z")`	all characters (and including) from 'a' to 'z' and 'A' and 'Z'
`char_("-1-9")`	'-' and all characters (and including) from '1' to '9'

Attributes

Expression	Attribute
`ch`	`unused`
`lit(ch)`	`unused`
`ns::char_`	`Ch`, attribute is mandatory (otherwise compilation will fail). `Ch` is the character type of the Character Encoding Namespace, `ns`.
`ns::char_(ch)`	`Ch`, attribute is optional, if it is supplied, the generator compares the attribute with `ch` and succeeds only if both are equal, failing otherwise. `Ch` is the character type of the Character Encoding Namespace, `ns`.
`ns::char_("c")`	`Ch`, attribute is optional, if it is supplied, the generator compares the attribute with `c` and succeeds only if both are equal, failing otherwise. `Ch` is the character type of the Character Encoding Namespace, `ns`.
`ns::char_(ch1, ch2)`	`Ch`, attribute is mandatory (otherwise compilation will fail), the generator succeeds if the attribute belongs to the character range `[ch1, ch2]` interpreted in the character set defined by `ns`. `Ch` is the character type of the Character Encoding Namespace, `ns`.
`ns::char_(cs)`	`Ch`, attribute is mandatory (otherwise compilation will fail), the generator succeeds if the attribute belongs to the character set `cs`, interpreted in the character set defined by `ns`. `Ch` is the character type of the Character Encoding Namespace, `ns`.
`~cg`	Attribute of `cg`

Note

In addition to their usual attribute of type `Ch` all listed generators accept an instance of a `boost::optional<Ch>` as well. If the `boost::optional<>` is initialized (holds a value) the generators behave as if their attribute was an instance of `Ch` and emit the value stored in the `boost::optional<>`. Otherwise the generators will fail.

Complexity

O(1)

The complexity of `ch`, `lit(ch)`, `ns::char_`, `ns::char_(ch)`, and `ns::char_("c")` is constant as all generators emit exactly one character per invocation.

The character range generator (`ns::char_(ch1, ch2)`) additionally requires constant lookup time for the verification whether the attribute belongs to the character range.

The character set generator (`ns::char_(cs)`) additionally requires O(log N) lookup time for the verification whether the attribute belongs to the character set, where N is the number of characters in the character set.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::lit;
using boost::spirit::ascii::char_;
```

Basic usage of `char_` generators:

```
test_generator("A", 'A');
test_generator("A", lit('A'));

test_generator_attr("a", char_, 'a');
test_generator("A", char_('A'));
test_generator_attr("A", char_('A'), 'A');
test_generator_attr("", char_('A'), 'B');         // fails (as 'A' != 'B')

test_generator_attr("A", char_('A', 'Z'), 'A');
test_generator_attr("", char_('A', 'Z'), 'a');    // fails (as 'a' does not belong to 'A'...'Z')

test_generator_attr("k", char_("a-z0-9"), 'k');
test_generator_attr("", char_("a-z0-9"), 'A');    // fails (as 'A' does not belong to "a-z0-9")
```

Character Classification (`alnum`, `digit`, etc.)

Description

The library has the full repertoire of single character generators for character classification. This includes the usual `alnum`, `alpha`, `digit`, `xdigit`, etc. generators. These generators have an associated Character Encoding Namespace. This is needed when doing basic operations such as forcing lower or upper case.

Header

```
// forwards to <boost/spirit/home/karma/char/char_class.hpp>
#include <boost/spirit/include/karma_char_class.hpp>
```

Also, see Include Structure.

Namespace

Name
ns::alnum
ns::alpha
ns::blank
ns::cntrl
ns::digit
ns::graph
ns::lower
ns::print
ns::punct
ns::space
ns::upper
ns::xdigit

In the table above, ns represents a Character Encoding Namespace used by the corresponding character class generator. All listed generators have a mandatory attribute Ch and will not compile if no attribute is associated.

Model of

PrimitiveGenerator

Notation

ns A Character Encoding Namespace.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in PrimitiveGenerator.

Expression	Semantics
`ns::alnum`	If the mandatory attribute satisfies the concept of `std::isalnum` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::alpha`	If the mandatory attribute satisfies the concept of `std::isalpha` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::blank`	If the mandatory attribute satisfies the concept of `std::isblank` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::cntrl`	If the mandatory attribute satisfies the concept of `std::iscntrl` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::digit`	If the mandatory attribute satisfies the concept of `std::isdigit` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::graph`	If the mandatory attribute satisfies the concept of `std::isgraph` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::print`	If the mandatory attribute satisfies the concept of `std::isprint` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::punct`	If the mandatory attribute satisfies the concept of `std::ispunct` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::xdigit`	If the mandatory attribute satisfies the concept of `std::isxdigit` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.

Expression	Semantics
`ns::lower`	If the mandatory attribute satisfies the concept of `std::islower` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::upper`	If the mandatory attribute satisfies the concept of `std::isupper` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.
`ns::space`	If the optional attribute satisfies the concept of `std::isspace` in the Character Encoding Namespace the generator succeeds after emitting its attribute (unless the underlying output stream reports an error). This generator fails otherwise while not generating anything.If no attribute is supplied this generator emits a single space character in the character set defined by `ns`.

Possible values for `ns` are described in the section Character Encoding Namespace.

Note

The generators `alpha` and `alnum` might seem to behave unexpected if used inside a `lower[]` or `upper[]` directive. Both directives additionally apply the semanitics of `std::islower` or `std::isupper` to the respective character class. Some examples:

```
std::string s;
std::back_insert_iterator<std::string> out(s);
generate(out, lower[alpha], 'a');               // succeeds emitting 'a'
generate(out, lower[alpha], 'A');               // fails
```

The generator directive `upper[]` behaves correspondingly.

Attributes

All listed character class generators can take any attribute `Ch`. All character class generators (except `space`) require an attribute and will fail compiling otherwise.

Note

In addition to their usual attribute of type `Ch` all listed generators accept an instance of a `boost::optional<Ch>` as well. If the `boost::optional<>` is initialized (holds a value) the generators behave as if their attribute was an instance of `Ch` and emit the value stored in the `boost::optional<>`. Otherwise the generators will fail.

Complexity

O(1)

The complexity is constant as the generators emit not more than one character per invocation.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::alpha;
using boost::spirit::karma::upper;
```

Basic usage of an `alpha` generator:

```
test_generator_attr("a", alpha, 'a');
test_generator_attr("A", alpha, 'A');
test_generator_attr("", alpha, '1');          // fails (as isalpha('1') is false)
test_generator_attr("A", upper[alpha], 'A');
test_generator_attr("", upper[alpha], 'a');   // fails (as isupper('a') is false)
```

Directive

This module includes different generator directives. It includes alignment directives (`left_align[]`, `center[]`, and `right_align[]`), repetition (`repeat[]`), directives controlling automatic delimiting (`verbatim[]` and `delimit[]`), controlling case sensitivity (`upper[]` and `lower[]`), field width (`maxwidth[]`), buffering (`buffer[]`), and attribute handling (`omit[]`).

Module Header

```
// forwards to <boost/spirit/home/karma/directive.hpp>
#include <boost/spirit/include/karma_directive.hpp>
```

Also, see Include Structure.

Alignment Directives (`left_align[]`, `center[]`, `right_align[]`)

Description

The alignment directives allow to left align, right align or center output emitted by other generators into columns of a specified width while using an arbitrary generator to create the padding.

Header

For the `left_align[]` directive:

```
// forwards to <boost/spirit/home/karma/directive/left_alignment.hpp>
#include <boost/spirit/include/karma_left_alignment.hpp>
```

For the `center[]` directive:

```
// forwards to <boost/spirit/home/karma/directive/center_alignment.hpp>
#include <boost/spirit/include/karma_center_alignment.hpp>
```

For the `right_align[]` directive:

```
// forwards to <boost/spirit/home/karma/directive/right_alignment.hpp>
#include <boost/spirit/include/karma_right_alignment.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::left_align // alias: boost::spirit::karma::left_align`
`boost::spirit::center // alias: boost::spirit::karma::center`
`boost::spirit::right_align // alias: boost::spirit::karma::right_align`

Model of

`UnaryGenerator`

Notation

`a`	A generator object
`pad`	A generator object, or a Lazy Argument that evaluates to a generator object
`A`, `Pad`	Attribute types of the generators `a` and `pad`
`width`	Numeric literal, any unsigned integer value, or a Lazy Argument that evaluates to an unsigned integer value

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`left_align[a]`	Generate `a` left aligned in a column of width as defined by the preprocessor constant `BOOST_KARMA_DEFAULT_FIELD_LENGTH` (default: 10), while using `space` to emit the necessary padding. This generator succeeds as long as its embedded generator `a` does not fail (unless the underlying output stream reports an error).
`left_align(width)[a]`	Generate `a` left aligned in a column of the given `width`, while using `space` to emit the necessary padding. This generator succeeds as long as its embedded generator `a` does not fail (unless the underlying output stream reports an error).
`left_align(pad)[a]`	Generate `a` left aligned in a column of width as defined by the preprocessor constant `BOOST_KARMA_DEFAULT_FIELD_LENGTH` (default: 10), while using the generator `pad` to emit the necessary padding. This generator succeeds as long as its embedded and padding generators `a` and `pad` do not fail (except if the underlying output stream reports an error).
`left_align(pad, width)[a]`	Generate `a` left aligned in a column of the given `width`, while using the generator `pad` to emit the necessary padding. This generator succeeds as long as its embedded and padding generators `a` and `pad` do not fail (unless the underlying output stream reports an error).
`center[a]`	Generate `a` centered in a column of width as defined by the preprocessor constant `BOOST_KARMA_DEFAULT_FIELD_LENGTH` (default: 10), while using `space` to emit the necessary padding. This generator succeeds as long as its embedded generator `a` does not fail (unless the underlying output stream reports an error).
`center(width)[a]`	Generate `a` centered in a column of the given `width`, while using `space` to emit the necessary padding. This generator succeeds as long as its embedded generator `a` does not fail (unless the underlying output stream reports an error).
`center(pad)[a]`	Generate `a` centered in a column of width as defined by the preprocessor constant `BOOST_KARMA_DEFAULT_FIELD_LENGTH` (default: 10), while using the generator `pad` to emit the necessary padding. This generator succeeds as long as its embedded and padding generators `a` and `pad` do not fail (except if the underlying output stream reports an error).
`center(pad, width)[a]`	Generate `a` centered in a column of the given `width`, while using the generator `pad` to emit the necessary padding. This generator succeeds as long as its embedded and padding generators `a` and `pad` do not fail (unless the underlying output stream reports an error).

Expression	Semantics
`right_align[a]`	Generate `a` right aligned in a column of width as defined by the preprocessor constant `BOOST_KARMA_DEFAULT_FIELD_LENGTH` (default: 10), while using `space` to emit the necessary padding. This generator succeeds as long as its embedded generator `a` does not fail (unless the underlying output stream reports an error).
`right_align(width)[a]`	Generate `a` right aligned in a column of the given `width`, while using `space` to emit the necessary padding. This generator succeeds as long as its embedded generator `a` does not fail (unless the underlying output stream reports an error).
`right_align(pad)[a]`	Generate `a` right aligned in a column of width as defined by the preprocessor constant `BOOST_KARMA_DEFAULT_FIELD_LENGTH` (default: 10), while using the generator `pad` to emit the necessary padding. This generator succeeds as long as its embedded and padding generators `a` and `pad` do not fail (except if the underlying output stream reports an error).
`right_align(pad, width)[a]`	Generate `a` right aligned in a column of the given `width`, while using the generator `pad` to emit the necessary padding. This generator succeeds as long as its embedded and padding generators `a` and `pad` do not fail (unless the underlying output stream reports an error).

Note

None of the generator directives listed above limits the emitted output to the respective column width. If the emitted output is longer than the specified (or implied) column width, the generated output overruns the column to the right.

If the output needs to be limitted to a specified column width, use the `maxwidth[]` directive, for instance:

```
maxwidth(8)[right_align(12)["1234567890"]]
```

which will output (without the quotes):

```
"  123456"
```

Attributes

See Compound Attribute Notation.

Expression	Attribute
`left_align[]`	`a: A --> left_align[a]: A` `a: Unused --> left_align[a]: Unused`
`left_align(width)[]`	`a: A --> left_align(width)[a]: A` `a: Unused --> left_align(width)[a]: Unused`

`left_align(pad)[]`	`a: A, pad: Pad --> left_align(pad)[a]: A`
	`a: Unused, pad: Pad --> left_align(pad)[a]: Un↵`
	`used`

`left_align(pad, width)[]`	`a: A, pad: Pad --> left_align(pad, width)[a]: A`
	`a: Un↵`
	`used, pad: Pad --> left_align(pad, width)[a]: Un↵`
	`used`

`center[]`	`a: A --> center[a]: A` `a: Unused --> center[a]: Unused`
`center(width)[]`	`a: A --> center(width)[a]: A` `a: Unused --> center(width)[a]: Unused`
`center(pad)[]`	`a: A, pad: Pad --> center(pad)[a]: A` `a: Unused, pad: Pad --> center(pad)[a]: Unused`

`center(pad, width)[]`	`a: A, pad: Pad --> center(pad, width)[a]: A`
	`a: Unused, pad: Pad --> cen↵`
	`ter(pad, width)[a]: Unused`

`right_align[]`	`a: A --> right_align[a]: A` `a: Unused --> right_align[a]: Unused`
`right_align(width)[]`	`a: A --> right_align(width)[a]: A` `a: Unused --> right_align(width)[a]: Unused`

`right_align(pad)[]`	`a: A, pad: Pad --> right_align(pad)[a]: A`
	`a: Un↵`
	`used, pad: Pad --> right_align(pad)[a]: Unused`

Expression	Attribute
`right_align(pad, width)[]`	`a: A, pad: Pad --> right_align(pad, width)[a]: A a: Un↵ used, pad: Pad --> right_align(pad, width)[a]: Un↵ used`

Complexity

The overall complexity of the alignment generator directives is defined by the complexity of its embedded and padding generator. The complexity of the left alignment directive generator itself is O(1). The complexity of the center and right alignment directive generators itself is O(N). where `N` is the number of characters emitted by the embedded and padding generators.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::left_align;
using boost::spirit::karma::center;
using boost::spirit::karma::right_align;
```

Basic usage of the alignment generators:

```
std::pair<double, double> p (1.0, 2.0);
test_generator_attr("1.0     |2.0", left_align(8)[double_] << '|' << double_, p);
test_generator_attr("   1.0  |2.0", center(8)[double_] << '|' << double_, p);
test_generator_attr("     1.0|2.0", right_align(8)[double_] << '|' << double_, p);
```

Repetition Directive (`repeat[]`)

Description

The repetition directive allows to repeat an arbitrary generator expression while optionally specifying the lower and upper repetition counts. It provides a more powerful and flexible mechanism for repeating a generator. There are grammars that are impractical and cumbersome, if not impossible, for the basic EBNF iteration syntax (unary `'*'` and the unary `'+'`) to specify. Examples:

- A file name may have a maximum of 255 characters only.
- A specific bitmap file format has exactly 4096 RGB color information.

- A 256 bit binary string (1..256 1s or 0s).

Header

```
// forwards to <boost/spirit/home/karma/directive/repeat.hpp>
#include <boost/spirit/include/karma_repeat.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::repeat // alias: boost::spirit::karma::repeat`
`boost::spirit::inf // alias: boost::spirit::karma::inf`

Model of

`UnaryGenerator`

Notation

`a`	A generator object
`num, num1, num2`	Numeric literals, any unsigned integer value, or a Lazy Argument that evaluates to an unsigned integer value
`inf`	Placeholder expression standing for 'no upper repeat limit'

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`repeat[a]`	Repeat the generator `a` zero or more times. This generator succeeds as long as its embedded generator `a` does not fail (except if the underlying output stream reports an error). This variant of `repeat[]` is semantically equivalent to the Kleene Star operator `*a`
`repeat(num)[a]`	Repeat the generator `a` exactly `num` times. This generator succeeds as long as its embedded generator `a` does not fail and as long as the associated attribute (container) contains at least `num` elements (unless the underlying output stream reports an error).
`repeat(num1, num2)[a]`	Repeat the generator `a` at least `num1` times but not more than `num2` times. This generator succeeds as long as its embedded generator `a` does not fail and as long as the associated attribute (container) contains at least `num1` elements (unless the underlying output stream reports an error). If the associated attribute (container) does contain more than `num2` elements, this directive limits the repeat count to `num2`.
`repeat(num, inf)[a]`	Repeat the generator `a` at least `num1` times. No upper limit for the repeat count is set. This generator succeeds as long as its embedded generator `a` does not fail and as long as the associated attribute (container) contains at least `num` elements (unless the underlying output stream reports an error).

Note

All failing iterations of the embedded generator will consume one element from the supplied attribute. The overall `repeat[a]` will succeed as long as the iteration criteria (number of successful invocations of the embedded generator) is fullfilled (unless the underlying output stream reports an error).

Attributes

See Compound Attribute Notation.

Expression	Attribute
`repeat[a]`	`a: A --> repeat[a]: vector<A>` `a: Unused --> repeat[a]: Unused`
`repeat(num)[a]`	`a: A --> repeat(num)[a]: vector<A>` `a: Unused --> repeat(num)[a]: Unused`
`repeat(num1, num2)[a]`	`a: A --> repeat(num1, num2)[a]: vector<A>` `a: Unused --> repeat(num1, num2)[a]: Unused`
`repeat(num, inf)[a]`	`a: A --> repeat(num, inf)[a]: vector<A>` `a: Unused --> repeat(num, inf)[a]: Unused`

Important

The table above uses `vector<A>` as placeholders only.

The notation of `vector<A>` stands for *any STL container* holding elements of type `A`.

It is important to note, that the `repeat[]` directive does not perform any buffering of the output generated by its embedded elements. That means that any failing element generator might have already generated some output, which is *not* rolled back.

Tip

The simplest way to force a `repeat[]` directive to behave as if it did buffering is to wrap it into a buffering directive (see `buffer`):

```
buffer[repeat[a]]
```

which will *not* generate any output in case of a failing generator `repeat[a]`. The expression:

```
repeat[buffer[a]]
```

will not generate any partial output from a generator `a` if it fails generating in the middle of its output. The overall expression will still generate the output as produced by all succeeded invocations of the generator `a`.

Complexity

The overall complexity of the repetition generator is defined by the complexity of its embedded generator. The complexity of the repeat itself is O(N), where N is the number of repetitions to execute.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::repeat;
```

Basic usage of `repeat` generator directive:

```
std::vector<double> v;
v.push_back(1.0);
v.push_back(2.0);
v.push_back(3.0);

test_generator_attr("[1.0][2.0][3.0]", repeat['[' << double_ << ']'], v);
test_generator_attr("[1.0][2.0]", repeat(2)['[' << double_ << ']'], v);

// fails because of insufficient number of items
test_generator_attr("", repeat(4)['[' << double_ << ']'], v);
```

Directives Controlling Automatic Delimiting (`verbatim[]`, `delimit[]`)

Description

The directives `delimit[]` and `verbatim[]` can be used to control automatic delimiting. The directive `verbatim[]` disables any automatic delimiting, while the directive `delimit[]` (re-)enables automatic delimiting.

Header

For the `verbatim[]` directive:

```
// forwards to <boost/spirit/home/karma/directive/verbatim.hpp>
#include <boost/spirit/include/karma_verbatim.hpp>
```

For the `delimit[]` directive:

```
// forwards to <boost/spirit/home/karma/directive/delimit.hpp>
#include <boost/spirit/include/karma_delimit.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::verbatim // alias: boost::spirit::karma::verbatim`
`boost::spirit::delimit // alias: boost::spirit::karma::delimit`

Model of

`UnaryGenerator`

Notation

`a`	A generator object
`d`	A generator object, or a Lazy Argument that evaluates to a generator object
`A`, `D`	Attribute types of the generators `a` and `d`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`delimit[a]`	Enable automatic delimiting for the embedded generator `a` while using the `space` generator as the delimiting generator. If used inside a `verbatim[]` directive it re-enables the delimiter generator as used outside of this `verbatim[]` instead. The directive succeeds as long as the embedded generator succeeded (unless the underlying output stream reports an error).
`delimit(d)[a]`	Enable automatic delimiting for the embedded generator `a` while using the generator `d` as the delimiting generator. The directive succeeds as long as the embedded generator succeeded (unless the underlying output stream reports an error).
`verbatim[a]`	Disable automatic delimiting for the embedded generator `a`. The directive succeeds as long as the embedded generator succeeded (unless the underlying output stream reports an error). This directive it has no effect if it is used when no delimiting is active.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`delimit[a]`	`a: A --> delimit[a]: A` `a: Unused --> delimit[a]: Unused`
`delimit(d)[a]`	`a: A, d: D --> delimit(d)[a]: A` `a: Unused, d: D --> delimit(d)[a]: Unused`
`verbatim[a]`	`a: A --> verbatim[a]: A` `a: Unused --> verbatim[a]: Unused`

Complexity

The overall complexity of the generator directives `delimit[]` and `verbatim[]` is defined by the complexity of its embedded generators. The complexity of the directives themselves is O(1).

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::delimit;
using boost::spirit::karma::verbatim;
```

Basic usage of `delimit` generator directive:

```
test_generator_attr("[ 2.0 , 4.3 ] ",
    delimit['[' << double_ << ',' << double_ << ']'], 2.0, 4.3);
test_generator_attr("[*2.0*,*4.3*]*",
    delimit('*')['[' << double_ << ',' << double_ << ']'], 2.0, 4.3);
test_generator_attr("[2.0, 4.3 ] ",
    delimit[verbatim['[' << double_ << ','] << double_ << ']'], 2.0, 4.3);
```

Directives Controlling Case Sensitivity (`upper[]`, `lower[]`)

Description

The generator directives `ns::lower[]` and `ns::upper[]` force their embedded generators to emit lower case or upper case only characters based on the interpretation of the generated characters in the character set defined by `ns` (see Character Encoding Namespace).

Header

```
// forwards to <boost/spirit/home/karma/directive/upper_lower_case.hpp>
#include <boost/spirit/include/karma_upper_lower_case.hpp>
```

Also, see Include Structure.

Namespace

Name
`ns::lower`
`ns::upper`

In the table above, `ns` represents a Character Encoding Namespace.

Model of

The model of `lower[]` and `upper[]` is the model of its subject generator.

Notation

`a` A generator object

`A` Attribute type of the generator `a`

`ns` A Character Encoding Namespace.

Expression Semantics

The `lower[]` and `upper[]` directives have no special generator semantics. They are pure modifier directives. They indirectly influence the way all subject generators work. They add information (the `tag::upper` or `tag::lower`) to the `Modifier` template parameter used while tranforming the `proto::expr` into the corresponding generator expression. This is achieved by the following specializations:

```
namespace boost { namespace spirit
{
    template <typename CharEncoding>
    struct is_modifier_directive<
            karma::domain
          , tag::char_code<tag::lower, CharEncoding> >
      : mpl::true_
    {};

    template <typename CharEncoding>
    struct is_modifier_directive<
            karma::domain
          , tag::char_code<tag::upper, CharEncoding> >
      : mpl::true_
}}
```

(for more details see the section describing the compilation process of the Boost.Proto expression into the corresponding parser expressions).

Expression	Semantics
`ns::lower[a]`	Generate `a` as lower case, interpreted in the character set defined by `ns`. The directive succeeds as long as the embedded generator succeeded (unless the underlying output stream reports an error).
`ns::upper[a]`	Generate `a` as upper case, interpreted in the character set defined by `ns`. The directive succeeds as long as the embedded generator succeeded (unless the underlying output stream reports an error).

Note

If both directives are 'active' with regard to a generator, the innermost of those directives takes precedence. For instance:

```
generate(sink, ascii::lower['A' << ascii::upper['b']])
```

will generate `"aB"` (without the quotes).

Further, the directives will have no effect on generators emitting characters not having an upper case or lower case equivalent in the character set defined by `ns`.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`ns:lower[a]`	`a: A --> ns:lower[a]: A` `a: Unused --> ns:lower[a]: Unused`
`ns:upper[a]`	`a: A --> ns:upper[a]: A` `a: Unused --> ns:upper[a]: Unused`

Complexity

The overall complexity of the generator directives `ns::lower[]` and `ns::upper[]` is defined by the complexity of its embedded generators. The directives themselves are compile time only directives, having no impact on runtime performance.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::ascii::upper;
using boost::spirit::ascii::lower;
```

Basic usage of the `upper` and `lower` generator directives:

```
test_generator_attr("abc:2.0e-06", lower["ABC:" << double_], 2e-6);
test_generator_attr("ABC:2.0E-06", upper["abc:" << double_], 2e-6);
```

Controlling the Maximum Field Width (`maxwidth[]`)

Description

The `maxwidth[]` directive allows to limit (truncate) the overall length of the output generated by the embedded generator.

Header

```
// forwards to <boost/spirit/home/karma/directive/maxwidth.hpp>
#include <boost/spirit/include/karma_maxwidth.hpp>
```

Also, see Include Structure.

Name
`boost::spirit::maxwidth // alias: boost::spirit::karma::maxwidth`

Model of

`UnaryGenerator`

Notation

`a` A generator object

`A` Attribute type of the generator `a`

`num` Numeric literal, any unsigned integer value, or a Lazy Argument that evaluates to an unsigned integer value

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`maxwidth[a]`	Limit the overall length of the emitted output of the embedded generator (including characters generated by automatic delimiting) to the number of characters as defined by the preprocessor constant `BOOST_KARMA_DEFAULT_FIELD_MAXWIDTH`. Any additional output is truncated. The directive succeeds as long as the embedded generator succeeded (unless the underlying output stream reports an error).
`maxwidth(num)[a]`	Limit the overall length of the emitted output of the embedded generator (including characters generated by automatic delimiting) to the number of characters as defined by `num`. Any additional output is truncated. The directive succeeds as long as the embedded generator succeeded (unless the underlying output stream reports an error).

Note

The `maxwidth[]` generator directive does not pad the generated output to fill the specified column width. If the emitted output is shorter than the specified (or implied) column width, the generated output will be more narrow than the column width.

If the output needs to always be equal to a specified column width, use one of the alignment directives `left_align[]`, `center[]`, or `right_align[]`, for instance:

```
maxwidth(8)[left_align(8)["1234"]]
```

which will output: `"1234 "` (without the quotes).

Attributes

See Compound Attribute Notation.

Expression	Attribute
`maxwidth[a]`	`a: A --> maxwidth[a]: A` `a: Unused --> maxwidth[a]: Unused`
`maxwidth(num)[a]`	`a: A --> maxwidth(num)[a]: A` `a: Unused --> maxwidth(num)[a]: Unused`

Complexity

The overall complexity of the generator directive `maxwidth[]` is defined by the complexity of its embedded generator. The complexity of the directive itself is O(N), where `N` is the number of characters generated by the maxwidth directive.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::maxwidth;
using boost::spirit::karma::left_align;
using boost::spirit::karma::right_align;
```

Basic usage of `maxwidth` generator directive:

```
test_generator("01234", maxwidth(5)["0123456789"]);
test_generator("  012", maxwidth(5)[right_align(12)["0123456789"]]);
test_generator("0123    ", maxwidth(8)[left_align(8)["0123"]]);
```

Temporary Output Buffering (`buffer[]`)

Description

All generator components (except the Alternative (|) generator) pass their generated output directly to the underlying output stream. If a generator fails halfway through, the output generated so far is not 'rolled back'. The buffering generator directive allows to avoid this unwanted output to be generated. It temporarily redirects the output produced by the embedded generator into a buffer. This buffer is flushed to the underlying stream only after the embedded generator succeeded, but is discarded otherwise.

Header

```
// forwards to <boost/spirit/home/karma/directive/buffer.hpp>
#include <boost/spirit/include/karma_buffer.hpp>
```

Also, see Include Structure.

Name
`boost::spirit::buffer // alias: boost::spirit::karma::buffer`

Model of

`UnaryGenerator`

Notation

`a` A generator object

`A` Attribute type of generator `a`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`buffer[a]`	The embedded generator `a` is invoked but its output is temporarily intercepted and stored in an internal buffer. If `a` succeeds the buffer content is flushed to the underlying output stream, otherwise the buffer content is discarded. The buffer directive succeeds as long as the embedded generator succeeded (unless the underlying output stream reports an error).

Tip

If you want to make the buffered generator succeed regardless of the outcome of the embedded generator, simply wrap the `buffer[a]` into an additional optional: `-buffer[a]` (see Optional (unary -)).

Attributes

See Compound Attribute Notation.

Expression	Attribute
`buffer[a]`	`a: A --> buffer[a]: A` `a: Unused --> buffer[a]: Unused`

Complexity

The overall complexity of the buffering generator directive is defined by the complexity of its embedded generator. The complexity of the buffering directive generator itself is O(N), where N is the number of characters buffered.

Example

> **Note**
>
> The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::buffer;
```

Basic usage of a buffering generator directive. It shows how the partial output generated in the first example does not show up in the generated output as the plus generator fails (no data is available, see Plus (unary +)).

```
std::vector<double> v;                  // empty container
test_generator_attr("", -buffer['[' << +double_ << ']'], v);

v.push_back(1.0);                       // now, fill the container
v.push_back(2.0);
test_generator_attr("[1.02.0]", buffer['[' << +double_ << ']'], v);
```

Consume Attribute (`omit[]`)

Description

Consumes the attribute type of the embedded generator without generating any output.

Header

```
// forwards to <boost/spirit/home/karma/directive/omit.hpp>
#include <boost/spirit/include/karma_omit.hpp>
```

Also, see Include Structure.

Name
`boost::spirit::omit // alias: boost::spirit::karma::omit`

Model of

`UnaryGenerator`

Notation

a A generator object

`A` Attribute type of generator `a`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`omit[a]`	The `omit` directive consumes the attribute type of the embedded generator `A` without generating any output. It succeeds always.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`omit[a]`	`a: A --> omit[a]: A` `a: Unused --> omit[a]: Unused`

Complexity

The overall complexity of the `omit` generator directive is O(1) as it does not generate any output.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::omit;
```

Basic usage of a `omit` generator directive. It shows how it consumes the first element of the provided attribute without generating anything, leaving the second element of the attribute to the non-wrapped `double_` generator.

```
std::pair<double, double> p (1.0, 2.0);
test_generator_attr("2.0", omit[double_] << double_, p);
```

Generally, this directive is helpful in situations, where the attribute type contains more information (elements) than need to be used to generate the required output. Normally in such situations we would resolve to use semantic actions to explicitly pass the correct parts of the overall attribute to the generators. The `omit` directive helps achieving the same without having to use semantic actions.

Consider the attribute type:

```
typedef fusion::vector<int, double, std::string> attribute_type;
```

where we need to generate output only from the first and last element:

```
typedef std::back_insert:iterator<std::string> iterator_type;

karma::rule<iterator_type, attribute_type()> r;
r = int_[_1 = phoenix::at_c<0>(_val)] << string[_1 = phoenix::at_c<2>(_val)];

std::string str;
iterator_type sink(str);
generate(sink, r, attribute_type(1, 2.0, "example"));  // will generate: '1example'
```

This is error prone and not really readable. The same can be achieved by using the `omit` directive:

```
r = int_ << omit[double_] << string;
```

which is at the same time more readable and more efficient as we don't have to use semantic actions.

Nonterminal

Module Headers

```
// forwards to <boost/spirit/home/karma/nonterminal.hpp>
#include <boost/spirit/include/karma_nonterminal.hpp>
```

Also, see Include Structure.

Rule

Description

The rule is a polymorphic generator that acts as a named place-holder capturing the behavior of a PEG expression assigned to it. Naming a Parsing Expression Grammar expression allows it to be referenced later and makes it possible for the rule to call itself. This is one of the most important mechanisms and the reason behind the word "recursive" in recursive descent output generation.

Header

```
// forwards to <boost/spirit/home/karma/nonterminal/rule.hpp>
#include <boost/spirit/include/karma_rule.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::karma::rule`

Synopsis

```
template <typename OutputIterator, typename A1, typename A2, typename A3>
struct rule;
```

Template parameters

Parameter	Description	Default
`OutputIterator`	The underlying output iterator type that the rule is expected to work on.	none
`A1`, `A2`, `A3`	Either `Signature`, `Delimiter` or `Locals` in any order. See table below.	See table below.

Here is more information about the template parameters:

Parameter	Description	Default
`Signature`	Specifies the rule's consumed (value to output) and inherited (arguments) attributes. More on this here: `Nonterminal`.	`unused_type`. When `Signature` defaults to `unused_type`, the effect is the same as specifying a signature of `void()` which is also equivalent to `unused_type()`
`Delimiter`	Specifies the rule's delimiter generator. Specify this if you want the rule to delimit the generated output.	`unused_type`
`Locals`	Specifies the rule's local variables. See `Nonterminal`.	`unused_type`

Model of

`Nonterminal`

Notation

`r, r2`	Rules
`g`	A generator expression
`OutputIterator`	The underlying output iterator type that the rule is expected to work on.
`A1`, `A2`, `A3`	Either `Signature`, `Delimiter` or `Locals` in any order.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `Nonterminal`.

Expression	Description
`rule<OutputIterator, A1, A2, A3> r(name);`	Rule declaration. `OutputIterator` is required. `A1, A2, A3` are optional and can be specified in any order. `name` is an optional string that gives the rule its name, useful for debugging.
`rule<OutputIterator, A1, A2, A3> r(r2);`	Copy construct rule `r` from rule `r2`.
`r = r2;`	Assign rule `r2` to `r`.
`r.alias()`	Return an alias of `r`. The alias is a generator that holds a reference to `r`. Reference semantics.
`r.copy()`	Get a copy of `r`.
`r = g;`	Rule definition
`r %= g;`	Auto-rule definition. The attribute of `g` should be compatible with the consumed attribute of `r`.

Attributes

The rule's generator attribute is `RT`: The consumed attribute of the rule. See `Attribute`

Complexity

The complexity is defined by the complexity of the RHS generator, `g`

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::karma::rule;
using boost::spirit::karma::int_;
using boost::spirit::ascii::space;
using boost::spirit::ascii::space_type;
```

Basic rule:

```
rule<output_iterator_type> r;
r = int_(123);
test_generator("123", r);
```

Rule with consumed attribute:

```
rule<output_iterator_type, int()> ra;
ra = int_;
test_generator_attr("123", ra, 123);
```

Rule with delimiter and consumed attribute:

```
rule<output_iterator_type, std::vector<int>(), space_type> rs;
rs = *int_;
std::vector<int> v;
v.push_back(123);
v.push_back(456);
v.push_back(789);
test_generator_attr_delim("123 456 789", rs, space, v);
```

Grammar

Description

The grammar encapsulates a set of rules (as well as primitive generators (`PrimitiveGenerator`) and sub-grammars). The grammar is the main mechanism for modularization and composition. Grammars can be composed to form more complex grammars.

Header

```
// forwards to <boost/spirit/home/karma/nonterminal/grammar.hpp>
#include <boost/spirit/include/karma_grammar.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::karma::grammar`

Synopsis

```
template <typename OutputIterator, typename A1, typename A2, typename A3>
struct grammar;
```

Template parameters

Parameter	Description	Default
`OutputIterator`	The underlying output iterator type that the rule is expected to work on.	none
`A1`, `A2`, `A3`	Either `Signature`, `Delimiter` or `Locals` in any order. See table below.	See table below.

Here is more information about the template parameters:

Parameter	Description	Default
`Signature`	Specifies the grammar's synthesized (return value) and inherited attributes (arguments). More on this here: `Nonterminal`.	`unused_type`. When `Signature` defaults to `unused_type`, the effect is the same as specifying a signature of `void()` which is also equivalent to `unused_type()`
`Delimiter`	Specifies the grammar's delimiter generator. Specify this if you want the grammer to delimit the generated output.	`unused_type`
`Locals`	Specifies the grammar's local variables. See `Nonterminal`.	`unused_type`

Model of

`Nonterminal`

Notation

`g` A grammar

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `Nonterminal`.

Expression	Semantics

`template <typename OutputIterator>`
`struct my_grammar : grammar<OutputIterat↵`
`or, A1, A2, A3>`
`{`
`  my_grammar() : my_gram↵`
`mar::base_type(start, name)`
`  {`
`  // Rule definitions`
`  start = /* ... */;`
`  }`
 	
`  rule<OutputIterator, A1, A2, A3> start;`
`  // more rule declarations...`
`};`
	Grammar definition. `name` is an optional string that gives the grammar its name, useful for debugging.

Note

The template parameters of a grammar and its start rule (the rule passed to the grammar's base class constructor) must match, otherwise you will see compilation errors.

Attributes

The generator attribute of the grammar is `RT`, its consumed attribute. See `Attribute`

Complexity

The complexity is defined by the complexity of the its definition.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some using declarations:

```
using boost::spirit::ascii::space_type;
using boost::spirit::ascii::space;
using boost::spirit::int_;
using boost::spirit::karma::grammar;
using boost::spirit::karma::rule;
```

Basic grammar usage:

```
struct num_list : grammar<output_iterator_type, space_type, std::vector<int>()>
{
    num_list() : base_type(start)
    {
        using boost::spirit::int_;
        num = int_;
        start = num << *(',' << num);
    }

    rule<output_iterator_type, space_type, std::vector<int>()> start;
    rule<output_iterator_type, space_type, int()> num;
};
```

How to use the example grammar:

```
num_list nlist;
std::vector<int> v;
v.push_back(123);
v.push_back(456);
v.push_back(789);
test_generator_attr_delim("123 , 456 , 789", nlist, space, v);
```

Numeric

The library includes a couple of predefined objects for generating booleans, signed and unsigned integers, and real numbers. These generators are fully parametric. Most of the important aspects of numeric generation can be finely adjusted to suit. This includes the radix base, the exponent, the fraction etc. Policies control the real number generators' behavior. There are some predefined policies covering the most common real number formats but the user can supply her own when needed.

The numeric parsers are fine tuned (employing loop unrolling and extensive template metaprogramming) with exceptional performance that rivals the low level C functions such as `ltoa`, `ssprintf`, and `_gcvt`. Benchmarks reveal up to 2X speed over the C counterparts (see here: Performance of Numeric Generators). This goes to show that you can write extremely tight generic C++ code that rivals, if not surpasses C.

Module Header

```
// forwards to <boost/spirit/home/karma/numeric.hpp>
#include <boost/spirit/include/karma_numeric.hpp>
```

Also, see Include Structure.

Unsigned Integer Number Generators (`uint_`, etc.)

Description

The `uint_generator` class is the simplest among the members of the numerics package. The `uint_generator` can generate unsigned integers of arbitrary length and size. The `uint_generator` generator can be used to generate ordinary primitive C/C++ integers or even user defined scalars such as bigints (unlimited precision integers) if the type follows certain expression requirements (for more information about the requirements, see below)). The `uint_generator` is a template class. Template parameters fine tune its behavior.

Header

```
// forwards to <boost/spirit/home/karma/numeric/uint.hpp>
#include <boost/spirit/include/karma_uint.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lit // alias: boost::spirit::karma::lit`
`boost::spirit::bin // alias: boost::spirit::karma::bin`
`boost::spirit::oct // alias: boost::spirit::karma::oct`
`boost::spirit::hex // alias: boost::spirit::karma::hex`
`boost::spirit::ushort_ // alias: boost::spirit::karma::ushort_`
`boost::spirit::ulong_ // alias: boost::spirit::karma::ulong_`
`boost::spirit::uint_ // alias: boost::spirit::karma::uint_`
`boost::spirit::ulong_long // alias: boost::spirit::karma::ulong_long`

Important

The generators `ulong_long` and `ulong_long(num)` are only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `unsigned long long` (64 bit) unsigned integer types).

Note

`lit` is reused by the String Generators, the Character Generators, and the Numeric Generators. In general, a char generator is created when you pass in a character, a string generator is created when you pass in a string, and a numeric generator is created when you use a numeric literal.

Synopsis

```
template <
    typename Num
  , unsigned Radix>
struct uint_generator;
```

Template parameters

Parameter	Description	Default
`Num`	The numeric base type of the numeric generator.	`unsigned int`
`Radix`	The radix base. This can be either 2: binary, 8: octal, 10: decimal and 16: hexadecimal.	10

Model of

`PrimitiveGenerator`

Notation

`num` Numeric literal, any unsigned integer value, or a Lazy Argument that evaluates to an unsigned integer value of type `Num`

`Num` Type of `num`: any unsigned integer type, or in case of a Lazy Argument, its return value

`Radix` An integer literal specifying the required radix for the output conversion. Valid values are `2`, `8`, `10`, and `16`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Semantics
`lit(num)`	Generate the unsigned integer literal `num` using the default formatting (radix is 10). This generator never fails (unless the underlying output stream reports an error).

`ushort`
`uint`
`ulong`
`ulong_long`
	Generate the unsigned integer provided by a mandatory attribute using the default formatting (radix is 10). This generator never fails (unless the underlying output stream reports an error).

`ushort(num)`
`uint(num)`
`ulong(num)`
`ulong_long(num)`
	Generate the unsigned integer provided by the immediate literal value the generator is initialized from using the default formatting (radix is 10). If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.

`bin`
`oct`
`hex`
	Generate the unsigned integer provided by a mandatory attribute using the default formatting and the corresponding radix (`bin`: radix is 2, `oct`: radix is 8, `hex`: radix is 16). This generator never fails (unless the underlying output stream reports an error).

`bin(num)`
`oct(num)`
`hex(num)`
	Generate the unsigned integer provided by the immediate literal value the generator is initialized from using the default formatting and the corresponding radix (`bin`: radix is 2, `oct`: radix is 8, `hex`: radix is 16). If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.

All generators listed in the table above (except `lit(num)`) are predefined specializations of the `uint_generator<Num, Radix>` basic unsigned integer number generator type described below. It is possible to directly use this type to create unsigned integer generators using a wide range of formatting options.

Expression	Semantics

`uint_generator<`
`  Num, Radix`
`>()`
	Generate the unsigned integer of type `Num` provided by a mandatory attribute using the specified `Radix` (possible values are `2`, `8`, `10`, and `16`, the default value is `10`).This generator never fails (unless the underlying output stream reports an error).

`uint_generator<`
`  Num, Radix`
`>()(num)`
	Generate the unsigned integer of type `Num` provided by the immediate literal value the generator is initialized from, using the specified `Radix` (possible values are `2`, `8`, `10`, and `16`, the default value is `10`). If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.

Additional Requirements

The following lists enumerate the requirements which must be met in order to use a certain type `Num` to instantiate and use a `uint_generator<Num, Radix>`.

If `boost::is_integral<Num>::value` is `true` the type `Num` must have defined:

- comparison operators for: `<`, `<=`, `==`, `!=`, `>`, and `>=`
- numeric operators for: `+`, `-`, `/`, `*`, and `%`

If `boost::is_integral<Num>::value` is `false` the type `Num` must have defined:

- comparison operators for: `<`, `<=`, `==`, `!=`, `>`, and `>=`
- numeric operators for: `+`, `-`, `/`, `*`, and `%`
- helper functions implementing the interface and the semantics of: `std::fmod`, `std::pow`, `std::lround`, `std::ltrunc`, `std::floor`, and `std::ceil`. These need to be defined in a way so that they will be found using argument dependent lookup (ADL).

Attributes

Expression	Attribute
`lit(num)`	`unused`
`ushort`	`unsigned short`, attribute is mandatory (otherwise compilation will fail)
`ushort(num)`	`unsigned short`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.
`uint`	`unsigned int`, attribute is mandatory (otherwise compilation will fail)
`uint(num)`	`unsigned int`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.
`ulong`	`unsigned long`, attribute is mandatory (otherwise compilation will fail)
`ulong(num)`	`unsigned long`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.
`ulong_long`	`unsigned long long`, attribute is mandatory (otherwise compilation will fail)
`ulong_long(num)`	`unsigned long long`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.

`bin`
`oct`
`hex`
	`unsigned int`, attribute is mandatory (otherwise compilation will fail)

`bin(num)`
`oct(num)`
`hex(num)`
	`unsigned int`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.

`uint_generator<`
`  Num, Radix`
`>()`
	`Num`, attribute is mandatory (otherwise compilation will fail)

`uint_generator<`
`  Num, Radix`
`>()(num)`
	`Num`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.

Note

In addition to their usual attribute of type `Num` all listed generators accept an instance of a `boost::optional<Num>` as well. If the `boost::optional<>` is initialized (holds a value) the generators behave as if their attribute was an instance of `Num` and emit the value stored in the `boost::optional<>`. Otherwise the generators will fail.

Complexity

O(N), where `N` is the number of digits needed to represent the generated integer number

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::uint_;
using boost::spirit::karma::lit;
```

Basic usage of an `uint` generator:

```
test_generator("2", lit(2U));
test_generator("2", uint_(2));
test_generator_attr("2", uint_(2), 2);
test_generator_attr("", uint_(2), 3);    // fails (as 2 != 3)!
test_generator_attr("2", uint_, 2);
```

Signed Integer Number Generators (`int_`, etc.)

Description

The `int_generator` can generate signed integers of arbitrary length and size. This is almost the same as the `uint_generator`. The only difference is the additional task of generating the `'+'` or `'-'` sign preceding the number. The class interface is the same as that of the `uint_generator`.

The `int_generator` generator can be used to emit ordinary primitive C/C++ integers or even user defined scalars such as bigints (unlimited precision integers) if the type follows certain expression requirements (for more information about the requirements, see below).

Header

```
// forwards to <boost/spirit/home/karma/numeric/int.hpp>
#include <boost/spirit/include/karma_int.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lit // alias: boost::spirit::karma::lit`
`boost::spirit::short_ // alias: boost::spirit::karma::short_`
`boost::spirit::int_ // alias: boost::spirit::karma::int_`
`boost::spirit::long_ // alias: boost::spirit::karma::long_`
`boost::spirit::long_long // alias: boost::spirit::karma::long_long`

Important

The generators `long_long` and `long_long(num)` are only available on platforms where the preprocessor constant `BOOST_HAS_LONG_LONG` is defined (i.e. on platforms having native support for `long long` (64 bit) integer types).

Note

`lit` is reused by the String Generators, the Character Generators, and the Numeric Generators. In general, a char generator is created when you pass in a character, a string generator is created when you pass in a string, and a numeric generator is created when you use a numeric literal.

Synopsis

```
template <
    typename T
  , unsigned Radix
  , bool force_sign>
struct int_generator;
```

Template parameters

Parameter	Description	Default
`T`	The numeric base type of the numeric parser.	`int`
`Radix`	The radix base. This can be either 2: binary, 8: octal, 10: decimal and 16: hexadecimal.	10
`force_sign`	If `true`, all numbers will have a sign (space for zero)	`false`

Model of

`PrimitiveGenerator`

Notation

`num`	Numeric literal, any signed integer value, or a Lazy Argument that evaluates to a signed integer value of type `Num`
`Num`	Type of `num`: any signed integer type
`Radix`	A constant integer literal specifying the required radix for the output conversion. Valid values are `2`, `8`, `10`, and `16`.
`force_sign`	A constant boolean literal specifying whether the generated number should always have a sign (`'+'` for positive numbers, `'-'` for negative numbers and a `' '` for zero).

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Semantics
`lit(num)`	Generate the integer literal `num` using the default formatting (radix is 10, sign is only printed for negative literals). This generator never fails (unless the underlying output stream reports an error).

`short_`
`int_`
`long_`
`long_long`
	Generate the integer provided by a mandatory attribute using the default formatting (radix is 10, sign is only printed for negative literals). This generator never fails (unless the underlying output stream reports an error).

`short_(num)`
`int_(num)`
`long_(num)`
`long_long(num)`
	Generate the integer provided by the immediate literal value the generator is initialized from using the default formatting (radix is 10, sign is only printed for negative literals). If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.

All generators listed in the table above (except `lit(num)`) are predefined specializations of the `int_generator<Num, Radix, force_sign>` basic integer number generator type described below. It is possible to directly use this type to create integer generators using a wide range of formatting options.

Expression	Semantics
`int_generator< Num, Radix, force_sign >()`	Generate the integer of type `Num` provided by a mandatory attribute using the specified `Radix` (possible values are `2`, `8`, `10`, and `16`, the default value is `10`). If `force_sign` is `false` (the default), a sign is only printed for negative literals. If `force_sign` is `true`, all numbers will be printed using a sign, i.e. `'-'` for negative numbers, `'+'` for positive numbers, and `' '` for zeros. This generator never fails (unless the underlying output stream reports an error).
`int_generator< Num, Radix, force_sign >()(num)`	Generate the integer of type `Num` provided by the immediate literal value the generator is initialized from, using the specified `Radix` (possible values are `2`, `8`, `10`, and `16`, the default value is `10`). If `force_sign` is `false` (the default), a sign is only printed for negative literals. If `force_sign` is `true`, all numbers will be printed using a sign, i.e. `'-'` for negative numbers, `'+'` for positive numbers, and `' '` for zeros. If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.

Additional Requirements

The following lists enumerate the requirements which must be met in order to use a certain type `Num` to instantiate and use a `int_generator<Num, Radix, force_sign>`.

If `boost::is_integral<Num>::value` is `true` the type `Num` must have defined:

- comparison operators for: `<`, `<=`, `==`, `!=`, `>`, and `>=`
- numeric operators for: `+`, `-`, `/`, `*`, `%`, and unary `-`

If `boost::is_integral<Num>::value` is `false` the type `Num` must have defined:

- comparison operators for: `<`, `<=`, `==`, `!=`, `>`, and `>=`
- numeric operators for: `+`, `-`, `/`, `*`, `%`, and unary `-`
- helper functions implementing the interface and the semantics of: `std::fmod`, `std::fabs`, `std::pow`, `std::lround`, `std::ltrunc`, `std::floor`, and `std::ceil`. These need to be defined in a way so that they will be found using argument dependent lookup (ADL).

Attributes

Expression	Attribute
`lit(num)`	`unused`
`short_`	`short`, attribute is mandatory (otherwise compilation will fail)
`short_(num)`	`short`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.
`int_`	`int`, attribute is mandatory (otherwise compilation will fail)
`int_(num)`	`int`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.
`long_`	`long`, attribute is mandatory (otherwise compilation will fail)
`long_(num)`	`long`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.
`long_long`	`long long`, attribute is mandatory (otherwise compilation will fail)
`long_long(num)`	`long long`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.

`int_generator<`
`  Num, Radix, force_sign`
`>()`
	`Num`, attribute is mandatory (otherwise compilation will fail)

`int_generator<`
`  Num, Radix, force_sign`
`>()(num)`
	`Num`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.

Note

In addition to their usual attribute of type `Num` all listed generators accept an instance of a `boost::optional<Num>` as well. If the `boost::optional<>` is initialized (holds a value) the generators behave as if their attribute was an instance of `Num` and emit the value stored in the `boost::optional<>`. Otherwise the generators will fail.

Complexity

O(N), where `N` is the number of digits needed to represent the generated integer number

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::int_;
using boost::spirit::karma::lit;
```

Basic usage of an `int_` generator:

```
test_generator("-2", lit(-2));
test_generator("-2", int_(-2));
test_generator_attr("-2", int_(-2), -2);
test_generator_attr("", int_(-2), 3);    // fails (as -2 != 3)!
test_generator_attr("-2", int_, -2);
```

Real Number Generators (`float_`, `double_`, etc.)

Description

The `real_generator` can generate real numbers of arbitrary length and size limited by its template parameter, `Num`. The numeric base type `Num` can be a user defined numeric type such as fixed_point (fixed point reals) and bignum (unlimited precision numbers) if the type follows certain expression requirements (for more information about the requirements, see below).

Header

```
// forwards to <boost/spirit/home/karma/numeric/real.hpp>
#include <boost/spirit/include/karma_real.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lit // alias: boost::spirit::karma::lit`
`boost::spirit::float_ // alias: boost::spirit::karma::float_`
`boost::spirit::double_ // alias: boost::spirit::karma::double_`
`boost::spirit::long_double // alias: boost::spirit::karma::long_double`

Note

`lit` is reused by the String Generators, the Character Generators, and the Numeric Generators. In general, a char generator is created when you pass in a character, a string generator is created when you pass in a string, and a numeric generator is created when you use a numeric literal.

Synopsis

```
template <typename Num, typename RealPolicies>
struct real_generator;
```

Template parameters

Parameter	Description	Default
`Num`	The type of the real number to generate.	`double`
`RealPolicies`	The policies to use while converting the real number.	`real_policies<Num>`

For more information about the type `RealPolicies` see below.

Model of

`PrimitiveGenerator`

Notation

`num` Numeric literal, any real number value, or a Lazy Argument that evaluates to a real number value of type `Num`

`Num` Type of `num`: any real number type

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Semantics
`lit(num)`	Generate the real number literal `num` using the default formatting (no trailing zeros, `fixed` representation for numbers `fabs(n) <= 1e5 && fabs(n) > 1e-3`, scientific representation otherwise, 3 fractional digits, sign is only printed for negative literals). This generator never fails (unless the underlying output stream reports an error).

`float_`
`double_`
`long_double`
	Generate the real number provided by a mandatory attribute using the default formatting (no trailing zeros, `fixed` representation for numbers `fabs(n) <= 1e5 && fabs(n) > 1e-3`, scientific representation otherwise, 3 fractional digits, sign is only printed for negative literals). This generator never fails (unless the underlying output stream reports an error).

`float_(num)`
`double_(num)`
`long_double(num)`
	Generate the real point number provided by the immediate literal value the generator is initialized from using the default formatting (no trailing zeros, `fixed` representation for numbers `fabs(n) <= 1e5 && fabs(n) > 1e-3`, scientific representation otherwise, 3 fractional digits, sign is only printed for negative literals). If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.

All generators listed in the table above (except `lit(num)`) are predefined specializations of the `real_generator<Num, RealPolicies>` basic real number generator type described below. It is possible to directly use this type to create real number generators using a wide range of formatting options.

Expression	Semantics

`real_generator<`
`  Num, RealPolicies`
`>()`
	Generate the real number of type `Num` provided by a mandatory attribute using the specified `RealPolicies`. This generator never fails (unless the underlying output stream reports an error).

`real_generator<`
`  Num, RealPolicies`
`>()(num)`
	Generate the real number of type `Num` provided by the immediate literal value the generator is initialized from using the specified `RealPolicies`. If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.

Additional Requirements

The following list enumerates the requirements which must be met in order to use a certain type `Num` to instantiate a `real_generator<Num, Policies>`.

In order to be usable as the first template parameter for `real_generator<>` the type `Num` must have defined:

- comparison operators for: `<`, `<=`, `==`, `!=`, `>`, and `>=`
- numeric operators for: `+`, `-`, `/`, `*`, and `%`

- functions implementing the interface and the semantics of: `std::fmod`, `std::pow`, `std::log10`, `std::lround`, `std::ltrunc`, `std::modf`, `std::floor`, and `std::ceil`. These need to be defined in a way so that they will be found using argument dependent lookup (ADL).
- a valid specialization of the type `std::numeric_limits<Num>` allowing for numeric property inspection.

Attributes

Expression	Attribute
`lit(num)`	`unused`
`float_`	`float`, attribute is mandatory (otherwise compilation will fail)
`float_(num)`	`float_`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.
`double_`	`double`, attribute is mandatory (otherwise compilation will fail)
`double_(num)`	`double`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.
`long_double`	`long double`, attribute is mandatory (otherwise compilation will fail)
`long_double(num)`	`long double`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.
`real_generator< Num, Policies >()`	`Num`, attribute is mandatory (otherwise compilation will fail)
`real_generator< Num, Policies >()(num)`	`Num`, attribute is optional, if it is supplied, the generator compares the attribute with `num` and succeeds only if both are equal, failing otherwise.

Note

In addition to their usual attribute of type `Num` all listed generators accept an instance of a `boost::optional<Num>` as well. If the `boost::optional<>` is initialized (holds a value) the generators behave as if their attribute was an instance of `Num` and emit the value stored in the `boost::optional<>`. Otherwise the generators will fail.

Real Number Formatting Policies

If special formatting of a real number is needed, overload the policy class `real_policies<Num>` and use it as a template parameter to the `real_generator<>` real number generator. For instance:

```
// define a new real number formatting policy
template <typename Num>
struct scientific_policy : real_policies<Num>
{
    // we want the numbers always to be in scientific format
    static int floatfield(Num n) { return fmtflags::scientific; }
};

// define a new generator type based on the new policy
typedef real_generator<double, scientific_policy<double> > science_type;
science_type const scientific = science_type();

// use the new generator
generate(sink, science_type(), 1.0);  // will output: 1.0e00
generate(sink, scientific, 0.1);      // will output: 1.0e-01
```

The template parameter `Num` should be the type to be formatted using the overloaded policy type. At the same time `Num` will be used as the attribute type of the created real number generator.

Real Number Formatting Policy Expression Semantics

A real number formatting policy should expose the following variables and functions:

Expression	Description

`template <typename Inserter`
`  , typename OutputIterator`
`  , typename Policies>`
`bool call (OutputIterator& sink, Num n`
`  , Policies const& p);`
	This is the main function used to generate the output for a real number. It is called by the real generator in order to perform the conversion. In theory all of the work can be implemented here, but the easiest way is to use existing functionality provided by the type specified by the template parameter `Inserter`. The default implementation of this functions is:
	`template <typename Inserter, typename Out↵putIterator`
	`  , typename Policies>`
	`static bool`
	`call (OutputIterator& sink, Num ↵`
	`n, Policies const& p)`
	`{`
	`    return Inserter::call_n(sink, n, p);`
	`}`
	`sink` is the output iterator to use for generation
	`n` is the real number to convert
	`p` is the instance of the policy type used to instantiate this real number generator.

`bool force_sign(Num n);`	The default behavior is to not to require generating a sign. If the function `force_sign()` returns true, then all generated numbers will have a sign (`'+'` or `'-'`, zeros will have a space instead of a sign). `n` is the real number to output. This can be used to adjust the required behavior depending on the value of this number.
`bool trailing_zeros(Num n);`	Return whether trailing zero digits have to be emitted in the fractional part of the output. If set, this flag instructs the real number generator to emit trailing zeros up to the required precision digits (as returned by the `precision()` function). `n` is the real number to output. This can be used to adjust the required behavior depending on the value of this number.

Expression	Description
`int floatfield(Num n);`	Decide, which representation type to use in the generated output. By default all numbers having an absolute value of zero or in between `0.001` and `100000` will be generated using the fixed format, all others will be generated using the scientific representation. The `trailing_zeros()` can be used to force the output of trailing zeros in the fractional part up to the number of digits returned by the `precision()` member function. The default is not to generate the trailing zeros. `n` is the real number to output. This can be used to adjust the formatting flags depending on the value of this number. The return value has to be either `fmtflags::scientific` (generate real number values in scientific notation) or `fmtflags::fixed` (generate real number values in fixed-point notation).
`unsigned precision(Num n);`	Return the maximum number of decimal digits to generate in the fractional part of the output. `n` is the real number to output. This can be used to adjust the required precision depending on the value of this number. If the trailing zeros flag is specified the fractional part of the output will be 'filled' with zeros, if appropriate. **Note:** If the trailing_zeros flag is not in effect additional semantics apply. See the description for the `fraction_part()` function below. Moreover, this precision will be limited to the value of `std::numeric_limits<T>::digits10 + 1`.

`template <bool ForceSign,`
`  typename OutputIterator>`
`bool integer_part(OutputIterator& sink`
`  , Num n, bool sign, bool force_sign);`
	This function is called to generate the integer part of the real number.
	
	`sink` is the output iterator to use for generation
	
	`n` is the absolute value of the integer part of the real number to convert (always non-negative)
	
	`sign` is the sign of the overall real number to convert.
	
	`force_sign` is a flag indicating whether a sign has to be generated even for non-negative numbers (this is the same as has been returned from the function `force_sign()` described above)
	
	The return value defines the outcome of the whole generator. If it is `false`, no further output is generated, immediately returning `false` from the calling `real_generator` as well. If it is `true`, normal output generation continues.

Expression	Description

`template <typename OutputIterator>`
`bool dot(OutputIterator& sink, Num n,`
`  unsigned precision);`
	This function is called to generate the decimal point.
	
	`sink` is the output iterator to use for generation
	
	`n` is the fractional part of the real number to convert. Note that this number is scaled such, that it represents the number of units which correspond to the value returned from the `precision()` function earlier. I.e. a fractional part of `0.01234` is represented as `1234` when the function `precision()` returned `5`.
	
	`precision` is the number of digits to emit as returned by the function `precision()` described above
	
	This is given to allow to decide, whether a decimal point has to be generated at all.
	
	Note: If the `trailing_zeros` flag is not in effect additional comments apply. See the description for the `fraction_part()` function below.
	
	The return value defines the outcome of the whole generator. If it is `false`, no further output is generated, immediately returning `false` from the calling `real_generator` as well. If it is `true`, normal output generation continues.

Expression	Description

`template <typename OutputIterator>`
`bool fraction_part(OutputIterator& sink, Num n`
`  , unsigned adjprec, unsigned precision);`
	This function is called to generate the fractional part of the number.
	
	`sink` is the output iterator to use for generation
	
	`n` is the fractional part of the real number to convert. Note that this number is scaled such, that it represents the number of units which correspond to the value returned from the `precision()` function earlier. I.e. a fractional part of `0.01234` is represented as `1234` when the function `precision()` returned `5`.
	
	`adjprec` is the corrected number of digits to emit (see note below)
	
	`precision` is the number of digits to emit as returned by the function `precision()` described above
	
	Note: If `trailing_zeros()` returns `false` the `adjprec` parameter will have been corrected from the value the `precision()` function returned earlier (defining the maximal number of fractional digits) in the sense, that it takes into account trailing zeros. I.e. a real number `0.0123` and a value of `5` returned from `precision()` will result in:
	
	`trailing_zeros()` returned `false`: `n` will be `123`, and `adjprec` will be `4` (as we need to print `0123`)
	
	`trailing_zeros()` returned `true`: `n` will be `1230`, and `adjprec` will be `5` (as we need to print `01230`)
	
	The missing preceding zeros in the fractional part have to be supplied by the implementation of this policy function.
	
	The return value defines the outcome of the whole generator. If it is `false`, no further output is generated, immediately returning `false` from the calling `real_generator` as well. If it is `true`, normal output generation continues.

`template <typename CharEncoding,`
`    typename Tag, typename OutputIterator>`
`bool exponent(`
`    OutputIterator& sink, long n);`
	This function is called to generate the exponential part of the number (this is called only if the `floatfield()` function returned the `fmtflags::scientific` flag).
	
	`sink` is the output iterator to use for generation
	
	`n` is the (signed) exponential part of the real number to convert.
	
	The template parameters `CharEncoding` and `Tag` are either of the type `unused_type` or describe the character class and conversion to be applied to any output possibly influenced by either the `lower[]` or `upper[]` directives.
	
	The return value defines the outcome of the whole generator. If it is `false`, no further output is generated, immediately returning `false` from the calling `real_generator` as well. If it is `true`, normal output generation continues.

Expression	Description
`template <typename CharEncoding , typename Tag, typename OutputIterator> bool nan (OutputIterator& sink, Num n , bool force_sign);`	This function is called whenever the number to print is a non-normal real number of type `NaN`. `sink` is the output iterator to use for generation `n` is the (signed) real number to convert `force_sign` is a flag indicating whether a sign has to be generated even for non-negative numbers (this is the same as has been returned from the function `force_sign()` described above) The template parameters `CharEncoding` and `Tag` are either of the type `unused_type` or describe the character class and conversion to be applied to any output possibly influenced by either the `lower[]` or `upper[]` directives. The return value defines the outcome of the whole generator. If it is `false`, no further output is generated, immediately returning `false` from the calling `real_generator` as well. If it is `true`, normal output generation continues.
`template <typename CharEncoding , typename Tag, typename OutputIterator> bool inf (OutputIterator& sink, Num n , bool force_sign);`	This function is called whenever the number to print is a non-normal real number of type `Inf`. `sink` is the output iterator to use for generation `n` is the (signed) real number to convert `force_sign` is a flag indicating whether a sign has to be generated even for non-negative numbers (this is the same as has been returned from the function `force_sign()` described above) The template parameters `CharEncoding` and `Tag` are either of the type `unused_type` or describe the character class and conversion to be applied to any output possibly influenced by either the `lower[]` or `upper[]` directives. The return value defines the outcome of the whole generator. If it is `false`, no further output is generated, immediately returning `false` from the calling `real_generator` as well. If it is `true`, normal output generation continues.

Tip

The easiest way to implement a proper real number formatting policy is to derive a new type from the the type `real_policies<>` while overriding the aspects of the formatting which need to be changed.

Complexity

O(N), where `N` is the number of digits needed to represent the generated real number.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::lit;
```

Basic usage of an `double_` generator:

```
test_generator("2.0", lit(2.0));
test_generator("2.0", double_(2));
test_generator_attr("2.0", double_(2.0), 2.0);
test_generator_attr("", double_(2.0), 3.0);    // fails (as 2.0 != 3.0)!
test_generator_attr("-2.0", double_, -2.0);

test_generator_attr("1.234e05", double_, 1234.0e2);
test_generator_attr("1.234e-06", double_, 0.000001234);
```

Boolean Generators (`bool_`)

Description

As you might expect, the `bool_generator` can generate output from boolean values. The `bool_generator` generator can be used to generate output from ordinary primitive C/C++ `bool` values or user defined boolean types if the type follows certain expression requirements (for more information about the requirements, see below)). The `bool_generator` is a template class. Template parameters fine tune its behavior.

Header

```
// forwards to <boost/spirit/home/karma/numeric/bool.hpp>
#include <boost/spirit/include/karma_bool.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lit // alias: boost::spirit::karma::lit`
`boost::spirit::bool_ // alias: boost::spirit::karma::bool_`
`boost::spirit::true_ // alias: boost::spirit::karma::true_`
`boost::spirit::false_ // alias: boost::spirit::karma::false_`

Note

`lit` is reused by the String Generators, the Character Generators, and the Numeric Generators. In general, a char generator is created when you pass in a character, a string generator is created when you pass in a string, and a numeric generator is created when you use a numeric (boolean) literal.

Synopsis

```
template <
    typename B
  , unsigned Policies>
struct bool_generator;
```

Template parameters

Parameter	Description	Default
`B`	The boolean base type of the boolean generator.	`bool`
`Policies`	The policies to use while converting the boolean.	`bool_policies<B>`

Model of

`PrimitiveGenerator`

Notation

`b` Boolean literal, or a Lazy Argument that evaluates to a boolean value of type `B`

`B` Type of `b`: any type usable as a boolean, or in case of a Lazy Argument, its return value

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Semantics
`lit(b)`	Generate the boolean literal `b` using the default formatting (`false` is generated as `"false"`, and `true` is generated as `"true"`). This generator never fails (unless the underlying output stream reports an error).
`bool_`	Generate the boolean value provided by a mandatory attribute using the default formatting (`false` is generated as `"false"`, and `true` is generated as `"true"`). This generator never fails (unless the underlying output stream reports an error).
`bool_(b)`	Generate the booelan value provided by the immediate literal value the generator is initialized from using the default formatting (`false` is generated as `"false"`, and `true` is generated as `"true"`). If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.
`true_`	Generate `"true"`. If this generator has an associated attribute it succeeds only if the attribute is `true` as well (unless the underlying output stream reports an error).
`false_`	Generate `"false"`. If this generator has an associated attribute it succeeds only if the attribute is `false` as well (unless the underlying output stream reports an error).

All generators listed in the table above (except `lit(num)`) are predefined specializations of the `bool_generator<B, Policies>` basic boolean generator type described below. It is possible to directly use this type to create boolean generators using a wide range of formatting options.

Expression	Semantics

`bool_generator<`
`  B, Policies`
`>()`
	Generate the boolean of type `B` provided by a mandatory attribute using the specified `Policies` This generator never fails (unless the underlying output stream reports an error).

`bool_generator<`
`  B, Policies`
`>()(b)`
	Generate the boolean of type `B` provided by the immediate literal value the generator is initialized from, using the specified `Policies`. If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.

Note

All boolean generators properly respect the `upper` and `lower` directives.

Additional Requirements

The following lists enumerate the requirements which must be met in order to use a certain type `B` to instantiate and use a `bool_generator<B, Policies>`.

The type `B`:

- must be (safely) convertible to `bool`

Attributes

Expression	Attribute
`bool_(b)`	`unused`
`bool_`	`bool`, attribute is mandatory (otherwise compilation will fail)
`bool_(b)`	`bool`, attribute is optional, if it is supplied, the generator compares the attribute with `b` and succeeds only if both are equal, failing otherwise.
`bool_generator< B, Policies >()`	`B`, attribute is mandatory (otherwise compilation will fail)
`bool_generator< B, Policies >()(b)`	`B`, attribute is optional, if it is supplied, the generator compares the attribute with `b` and succeeds only if both are equal, failing otherwise.

Note

In addition to their usual attribute of type `B` all listed generators accept an instance of a `boost::optional<B>` as well. If the `boost::optional<>` is initialized (holds a value) the generators behave as if their attribute was an instance of `B` and emit the value stored in the `boost::optional<>`. Otherwise the generators will fail.

Boolean Formatting Policies

If special formatting of a boolean is needed, overload the policy class `bool_policies<B>` and use it as a template parameter to the `bool_generator<>` boolean generator. For instance:

```
struct special_bool_policy : karma::bool_policies<>
{
    template <typename CharEncoding, typename Tag
      , typename OutputIterator>
    static bool generate_false(OutputIterator& sink, bool b)
    {
        // we want to spell the names of false as eurt (true backwards)
        return string_inserter<CharEncoding, Tag>::call(sink, "eurt");
    }
};

typedef karma::bool_generator<special_bool_policy> backwards_bool_type;
backwards_bool_type const backwards_bool;

karma::generate(sink, backwards_bool, true);    // will output: true
karma::generate(sink, backwards_bool(false));   // will output: uert
```

The template parameter `B` should be the type to be formatted using the overloaded policy type. At the same time `B` will be used as the attribute type of the created real number generator. The default for `B` is `bool`.

Booelan Formatting Policy Expression Semantics

A boolean formatting policy should expose the following:

Expression	Description

`template <typename Inserter`
`  , typename OutputIterator`
`  , typename Policies>`
`bool call (OutputIterator& sink, Num n`
`  , Policies const& p);`
	This is the main function used to generate the output for a boolean. It is called by the boolean generator in order to perform the conversion. In theory all of the work can be implemented here, but the easiest way is to use existing functionality provided by the type specified by the template parameter `Inserter`. The default implementation of this functions is:
	`template <typename Inserter, typename Out↵putIterator`
	`  , typename Policies>`
	`static bool`
	`call (OutputIterator& sink, B ↵`
	`b, Policies const& p)`
	`{`
	`  return Inserter::call_n(sink, b, p);`
	`}`
	`sink` is the output iterator to use for generation
	`b` is the boolean to convert
	`p` is the instance of the policy type used to instantiate this real number generator.

`template <typename CharEncoding,`
`  typename Tag, typename OutputIterator>`
`bool generate_false(`
`  OutputIterator& sink, B b);`
	This function is called to generate the boolean if it is `false`.
	`sink` is the output iterator to use for generation
	`b` is the boolean to convert (the value is `false`).
	The template parameters `CharEncoding` and `Tag` are either of the type `unused_type` or describe the character class and conversion to be applied to any output possibly influenced by either the `lower[]` or `upper[]` directives.
	The return value defines the outcome of the whole generator.

`template <typename CharEncoding,`
`  typename Tag, typename OutputIterator>`
`bool generate_true(`
`  OutputIterator& sink, B b);`
	This function is called to generate the boolean if it is `true`.
	`sink` is the output iterator to use for generation
	`b` is the boolean to convert (the value is `true`).
	The template parameters `CharEncoding` and `Tag` are either of the type `unused_type` or describe the character class and conversion to be applied to any output possibly influenced by either the `lower[]` or `upper[]` directives.
	The return value defines the outcome of the whole generator.

Complexity

O(N), where `N` is the number of characters needed to represent the generated boolean.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::bool_;
using boost::spirit::karma::lit;
```

Basic usage of an `bool_` generator:

```
test_generator("true", lit(true));
test_generator("false", bool_(false));
test_generator_attr("true", bool_(true), true);
test_generator_attr("", bool_(true), false);    // fails (as true != false)!
test_generator_attr("false", bool_, false);
```

Operator

Operators are used as a means for object composition and embedding. Simple generators may be composed to form composites through operator overloading, crafted to approximate the syntax of Parsing Expression Grammar (PEG). An expression such as:

```
a | b
```

yields a new generator type which is a composite of its operands, `a` and `b`.

This module includes different generators which get instantiated if one of the overloaded operators is used with more primitive generator constructs. It includes sequences (`a << b`), alternatives (`a | b`), Kleene star (unary `*`), plus (unary `+`), optional (unary `-`), lists (`a % b`), and the two predicates, the *and* predicate (unary `&`) and the *not* predicate (unary `!`).

Module Header

```
// forwards to <boost/spirit/home/karma/operator.hpp>
#include <boost/spirit/include/karma_operator.hpp>
```

Also, see Include Structure.

Sequences (`a << b`)

Description

Generator sequences are used to consecutively combine different, more primitive generators. All generators in a sequence are invoked from left to right as long as they succeed.

Header

```
// forwards to <boost/spirit/home/karma/operator/sequence.hpp>
#include <boost/spirit/include/karma_sequence.hpp>
```

Also, see Include Structure.

Model of

NaryGenerator

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in NaryGenerator.

Expression	Semantics
`a << b`	The generators `a` and `b` are executed sequentially from left to right and as long as they succeed. A failed generator stops the execution of the entire sequence and makes the sequence fail as well.

It is important to note, that sequences don't perform any buffering of the output generated by its elements. That means that any failing sequence might have already generated some output, which is *not* rolled back.

Tip

The simplest way to force a sequence to behave as if it did buffering is to wrap it into a buffering directive (see buffer):

```
buffer[a << b << c]
```

which will *not* generate any output in case of a failing sequence.

Attributes

See Compound Attribute Notation.

Expression	Attribute

`a << b` (sequence)	`a: A, b: B --> (a << b): tuple<A, B>`
	`a: A, b: Unused --> (a << b): A`
	`a: Unused, b: B --> (a << b): B`
	`a: Unused, b: Unused --> (a << b): Unused`
	
	`a: A, b: A --> (a << b): vector<A>`
	`a: vector<A>, b: A --> (a << b): vector<A>`
	`a: A, b: vector<A> --> (a << b): vector<A>`
	`a: vector<A>, b: vector<A> --> (a << b): vec↵tor<A>`

Important

The table above uses `tuple<A, B>` and `vector<A>` as placeholders only.

The notation `tuple<A, B>` stands for *any fusion sequence of two elements*, where `A` is the type of its first element and `B` is the type of its second element.

The notation of `vector<A>` stands for *any STL container* holding elements of type `A`.

The attribute composition and propagation rules as shown in the table above make sequences somewhat special as they can operate in two modes if all elements have the same attribute type: consuming fusion sequences and consuming STL containers. The selected mode depends on the type of the attribute supplied.

Complexity

The overall complexity of the sequence generator is defined by the sum of the complexities of its elements. The complexity of the sequence itself is O(N), where N is the number of elements in the sequence.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
```

Basic usage of a sequence:

```
test_generator_attr("1.0,2.0", double_ << ',' << double_, std::make_pair(1.0, 2.0));
```

Alternative (`a | b`)

Description

Generator alternatives are used to combine different, more primitive generators into alternatives. All generators in an alternative are invoked from left to right until one of them succeeds.

Header

```
// forwards to <boost/spirit/home/karma/operator/alternative.hpp>
#include <boost/spirit/include/karma_alternative.hpp>
```

Also, see Include Structure.

Model of

NaryGenerator

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in NaryGenerator.

Expression	Semantics
a | b	The generators a and b are executed sequentially from left to right until one of them succeeds. A failed generator forces the alternative generator to try the next one. The alternative fails as a whole only if all elements of the alternative fail. Each element of the alternative gets passed the whole attribute of the alternative.

Alternatives intercept and buffer the output of the currently executed element. This allows to avoid partial outputs from failing elements as the buffered content will be forwarded to the actual output only after an element succeeded.

Attributes

See Compound Attribute Notation.

Expression	Attribute
a | b (alternative)	a: A, b: B --> (a | b): variant<A, B> a: A, b: Unused --> (a | b): A a: Unused, b: B --> (a | b): B a: Unused, b: Unused --> (a | b): Unused a: A, b: A --> (a | b): A

Important

The table above uses variant<A, B> as a placeholder only. The notation variant<A, B> stands for the type boost::variant<A, B>.

The attribute handling of Alternatives is special as their behavior is not completely defined at compile time. First of all the selected alternative element depends on the actual type of the attribute supplied to the alternative generator (i.e. what is stored in the variant). The attribute type supplied at *runtime* narrows the set of considered alternatives to those being compatible attribute wise. The remaining alternatives are tried sequentially until the first of them succeeds. See below for an example of this behavior.

Complexity

The overall complexity of the alternative generator is defined by the sum of the complexities of its elements. The complexity of the alternative itself is O(N), where N is the number of elements in the alternative.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::ascii::string;
```

Basic usage of an alternative. While being only the second alternative, the `double_` generator is chosen for output formatting because the supplied attribute type is not compatible (i.e. not convertible) to the attribute type of the `string` alternative.

```
boost::variant<std::string, double> v1(1.0);
test_generator_attr("1.0", string | double_, v1);
test_generator_attr("2.0", string | double_, 2.0);
```

The same formatting rules may be used to output a string. This time we supply the string `"example"`, resulting in the first alternative to be chosen for the generated output.

```
boost::variant<std::string, double> v2("example");
test_generator_attr("example", string | double_, v2);
test_generator_attr("example", string | double_, "example");
```

Kleene Star (`*a`)

Description

Kleene star generators are used to repeat the execution of an embedded generator zero or more times. Regardless of the success of the embedded generator, the Kleene star generator always succeeds.

Header

```
// forwards to <boost/spirit/home/karma/operator/kleene.hpp>
#include <boost/spirit/include/karma_kleene.hpp>
```

Also, see Include Structure.

Model of

`UnaryGenerator`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`*a`	The generator `a` is executed zero or more times depending on the availability of an attribute. The execution of `a` stops after the attribute values passed to the Kleene star generator are exhausted. The Kleene star always succeeds (unless the underlying output stream reports an error).

Note

All failing iterations of the embedded generator will consume one element from the supplied attribute.

Attributes

See Compound Attribute Notation.

Expression	Attribute
*a (Kleene star, unary *)	a: A --> *a: vector<A> a: Unused --> *a: Unused

Important

The table above uses vector<A> as a placeholder only. The notation of vector<A> stands for *any STL container* holding elements of type A.

The Kleene star generator will execute its embedded generator once for each element in the provided container attribute as long as the embedded generator succeeds. On each iteration it will pass the next consecutive element from the container attribute to the embedded generator. Therefore the number of iterations will not be larger than the number of elements in the container passed as its attribute. An empty container will make the Kleene star generate no output at all.

It is important to note, that the Kleene star does not perform any buffering of the output generated by its embedded elements. That means that any failing element generator might have already generated some output, which is *not* rolled back.

Tip

The simplest way to force a Kleene star to behave as if it did buffering is to wrap it into a buffering directive (see buffer):

```
buffer[*a]
```

which will *not* generate any output in case of a failing generator *a. The expression:

```
*(buffer[a])
```

will not generate any partial output from a generator a if it fails generating in the middle of its output. The overall expression will still generate the output as produced by all successful invocations of the generator a.

Complexity

The overall complexity of the Kleene star generator is defined by the complexity of its embedded generator multiplied by the number of executed iterations. The complexity of the Kleene star itself is O(N), where N is the number of elements in the container passed as its attribute.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::space;
```

Basic usage of a Kleene star generator:

```
std::vector<double> v;
v.push_back(1.0);
v.push_back(2.0);
v.push_back(3.0);
test_generator_attr_delim("1.0 2.0 3.0 ", *double_, space, v);
```

Plus (+a)

Description

The Plus generator is used to repeat the execution of an embedded generator one or more times. It succeeds if the embedded generator has been successfully executed at least once.

Header

```
// forwards to <boost/spirit/home/karma/operator/plus.hpp>
#include <boost/spirit/include/karma_plus.hpp>
```

Also, see Include Structure.

Model of

`UnaryGenerator`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`+a`	The generator `a` is executed one or more times depending on the availability of an attribute. The execution of `a` stops after the attribute values passed to the plus generator are exhausted. The plus generator succeeds as long as its embedded generator has been successfully executed at least once (unless the underlying output stream reports an error).

Note

All failing iterations of the embedded generator will consume one element from the supplied attribute. The overall `+a` will succeed as long as at least one invocation of the embedded generator will succeed (unless the underlying output stream reports an error).

Attributes

See Compound Attribute Notation.

Expression	Attribute
`+a` (unary +)	`a: A --> +a: vector<A>` `a: Unused --> +a: Unused`

Important

The table above uses `vector<A>` as a placeholder only. The notation of `vector<A>` stands for *any STL container* holding elements of type `A`.

The Plus generator will execute its embedded generator once for each element in the provided container attribute as long as the embedded generator succeeds. On each iteration it will pass the next consecutive element from the container attribute to the embedded generator. Therefore the number of iterations will not be larger than the number of elements in the container passed as its attribute. An empty container will make the plus generator fail.

It is important to note, that the plus generator does not perform any buffering of the output generated by its embedded elements. That means that any failing element generator might have already generated some output, which is *not* rolled back.

Tip

The simplest way to force a plus generator to behave as if it did buffering is to wrap it into a buffering directive (see `buffer`):

```
buffer[+a]
```

which will *not* generate any output in case of a failing generator `+a`. The expression:

```
+(buffer[a])
```

will not generate any partial output from a generator `a` if it fails generating in the middle of its output. The overall expression will still generate the output as produced by all successful invocations of the generator `a`.

Complexity

The overall complexity of the plus generator is defined by the complexity of its embedded generator multiplied by the number of executed iterations. The complexity of the plus generator itself is O(N), where N is the number of elements in the container passed as its attribute.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::space;
```

Basic usage of a plus generator:

```
std::vector<double> v1;
v1.push_back(1.0);
v1.push_back(2.0);
v1.push_back(3.0);
test_generator_attr_delim("1.0 2.0 3.0 ", +double_, space, v1);
```

A more sophisticated use case showing how to leverage the fact that plus is failing for empty containers passed as its attribute:

```
std::vector<double> v2;               // empty container
test_generator_attr("empty", +double_ | "empty", v2);
```

Lists (`a % b`)

Description

The list generator is used to repeat the execution of an embedded generator and interspace it with the output of another generator one or more times. It succeeds if the embedded generator has been successfully executed at least once.

Header

```
// forwards to <boost/spirit/home/karma/operator/list.hpp>
#include <boost/spirit/include/karma_list.hpp>
```

Also, see Include Structure.

Model of

`BinaryGenerator`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `BinaryGenerator`.

Expression	Semantics
`a % b`	The generator `a` is executed one or more times depending on the availability of an attribute. The output generated by `a` is interspaced with the output generated by `b`. The list generator succeeds if its first embedded generator has been successfully executed at least once (unless the underlying output stream reports an error).

The list expression `a % b` is a shortcut for `a << *(b << a)`. It is almost semantically equivalent, except for the attribute of `b`, which gets ignored in the case of the list generator.

Note

All failing iterations of the embedded generator will consume one element from the supplied attribute. The overall `a % b` will succeed as long as at least one invocation of the embedded generator, `a`, will succeed (unless the underlying output stream reports an error).

Attributes

See Compound Attribute Notation.

Expression	Attribute
`a % b` (list)	`a: A, b: B --> (a % b): vector<A>` `a: Unused, b: B --> (a % b): Unused`

Important

The table above uses `vector<A>` as a placeholder only. The notation of `vector<A>` stands for *any STL container* holding elements of type `A`.

The list generator will execute its embedded generator once for each element in the provided container attribute and as long as the embedded generator succeeds. The output generated by its first generator will be interspaced by the output generated by the second generator. On each iteration it will pass the next consecutive element from the container attribute to the first embedded generator. The second embedded generator does not get passed any attributes (it gets invoked using an `unused_type` as its attribute). Therefore the number of iterations will not be larger than the number of elements in the container passed as its attribute. An empty container will make the list generator fail.

Tip

If you want to use the list generator and still allow for an empty attribute, you can use the optional operator (see Optional (unary -)):

```
-(a % b)
```

which will succeed even if the provided container attribute does not contain any elements.

Complexity

The overall complexity of the list generator is defined by the complexity of its embedded generators multiplied by the number of executed iterations. The complexity of the list generator itself is O(N), where N is the number of elements in the container passed as its attribute.

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
```

Basic usage of a list generator:

```
std::vector<double> v1;
v1.push_back(1.0);
test_generator_attr("1.0", double_ % ',', v1);

v1.push_back(2.0);
test_generator_attr("1.0,2.0", double_ % ',', v1);
```

Optional (-a)

Description

The optional generator is used to conditionally execute an embedded generator. It succeeds always.

Header

```
// forwards to <boost/spirit/home/karma/operator/optional.hpp>
#include <boost/spirit/include/karma_optional.hpp>
```

Also, see Include Structure.

Model of

`UnaryGenerator`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`-a`	The generator `a` is executed depending on the availability of an attribute. The optional generator succeeds if its embedded generator succeeds (unless the underlying output stream reports an error).

Attributes

See Compound Attribute Notation.

Expression	Attribute
`-a` (optional, unary `-`)	`a: A --> -a: optional<A>` `a: Unused --> -a: Unused`

Important

The table above uses `optional<A>` as a placeholder only. The notation of `optional<A>` stands for the data type `boost::optional<A>`.

The optional generator will execute its embedded generator once if the provided attribute holds a valid value. It forwards the value held in its attribute to the embedded generator.

It is important to note, that the optional generator does not perform any buffering of the output generated by its embedded elements. That means that any failing element might have already generated some output, which is *not* rolled back.

Tip

The simplest way to force a optional generator to behave as if it did buffering is to wrap it into a buffering directive (see `buffer`):

```
buffer[-a]
```

which will *not* generate any output in case of a failing generator `-a`.

Complexity

The overall complexity of the optional generator is defined by the complexity of its embedded generator. The complexity of the optional generator itself is O(1).

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
```

Basic usage of an optional generator:

```
boost::optional<double> val(1.0);
test_generator_attr("1.0", -double_, val);
test_generator_attr("2.0", -double_, 2.0);
```

Usage and result of an empty optional generator:

```
boost::optional<double> val;          // empty optional
test_generator_attr("", -double_, val);
```

And Predicate (&a)

Description

The and predicate generator is used to test, whether the embedded generator succeeds without generating any output. It succeeds if the embedded generator succeeds.

Header

```
// forwards to <boost/spirit/home/karma/operator/and_predicate.hpp>
#include <boost/spirit/include/karma_and_predicate.hpp>
```

Also, see Include Structure.

Model of

`UnaryGenerator`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`&a`	The generator `a` is executed for the sole purpose of testing whether it succeeds. The and predicate generator succeeds if its embedded generator succeeds (unless the underlying output stream reports an error). The and predicate never produces any output.

The and generator is implemented by redirecting all output produced by its embedded generator into a discarding device.

Attributes

See Compound Attribute Notation.

Expression	Attribute
&a (and predicate, unary &)	a: A --> &a: A

Note

The attribute of the and predicate is not always unused_type, which is different from Qi's and predicate. This is necessary as the generator the and predicate is attached to most of the time needs an attribute.

Complexity

The overall complexity of the and predicate generator is defined by the complexity of its embedded generator. The complexity of the and predicate generator itself is O(1).

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::ascii::char_;
using boost::spirit::karma::ascii::string;
using boost::phoenix::ref;
```

Basic usage of an and predicate generator:

```
test_generator_attr("b", &char_('a') << 'b' | 'c', 'a');
test_generator_attr("c", &char_('a') << 'b' | 'c', 'x');

test_generator_attr("abc", &string("123") << "abc" | "def", "123");
test_generator_attr("def", &string("123") << "abc" | "def", "456");
```

Not Predicate (!a)

Description

The not predicate generator is used to test, whether the embedded generator fails, without generating any output. It succeeds if the embedded generator fails.

Header

```
// forwards to <boost/spirit/home/karma/operator/not_predicate.hpp>
#include <boost/spirit/include/karma_not_predicate.hpp>
```

Also, see Include Structure.

Model of

`UnaryGenerator`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `UnaryGenerator`.

Expression	Semantics
`!a`	The generator `a` is executed for the sole purpose of testing whether it succeeds. The not predicate generator succeeds if its embedded generator fails (unless the underlying output stream reports an error). The not predicate never produces any output.

The not generator is implemented by redirecting all output produced by its embedded generator into a discarding device.

Attributes

See Compound Attribute Notation.

Expression	Attribute
`!a` (not predicate, unary `!`)	`a: A --> !a: A`

Note

The attribute of the not predicate is not always `unused_type`, which is different from Qi's not predicate. This is necessary as the generator the and predicate is attached to most of the time needs an attribute.

Complexity

The overall complexity of the not predicate generator is defined by the complexity of its embedded generator. The complexity of the not predicate generator itself is O(1).

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::double_;
using boost::spirit::karma::ascii::char_;
using boost::spirit::karma::ascii::string;
using boost::phoenix::ref;
```

Basic usage of a not predicate generator:

```
test_generator_attr("c", !char_('a') << 'b' | 'c', 'a');
test_generator_attr("b", !char_('a') << 'b' | 'c', 'x');

test_generator_attr("def", !string("123") << "abc" | "def", "123");
test_generator_attr("abc", !string("123") << "abc" | "def", "456");
```

Stream

This module includes the description of the different variants of the `stream` generator. It can be used to utilize existing streaming operators (`operator<<(std::ostream&, ...)`) for output generation.

Header

```
// forwards to <boost/spirit/home/karma/stream.hpp>
#include <boost/spirit/include/karma_stream.hpp>
```

Also, see Include Structure.

Stream (`stream`, `wstream`, etc.)

Description

The `stream_generator` is a primitive which allows to use pre-existing standard streaming operators for output generation integrated with *Spirit.Karma*. It provides a wrapper generator dispatching the value to output to the stream operator of the corresponding type. Any value `a` to be formatted using the `stream_generator` will result in invoking the standard streaming operator for its type `A`, for instance:

```
std::ostream& operator<< (std::ostream&, A const&);
```

Header

```
// forwards to <boost/spirit/home/karma/stream.hpp>
#include <boost/spirit/include/karma_stream.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::stream // alias: boost::spirit::karma::stream`
`boost::spirit::wstream // alias: boost::spirit::karma::wstream`

Synopsis

```
template <typename Char>
struct stream_generator;
```

Template parameters

Parameter	Description	Default
`Char`	The character type to use to generate the output. This type will be used while assigning the generated characters to the underlying output iterator.	`char`

Model of

`PrimitiveGenerator`

Notation

s A variable instance of any type with a defined matching streaming `operator<<()` or a Lazy Argument that evaluates to any type with a defined matching streaming `operator<<()`.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Description
`stream`	Call the streaming `operator<<()` for the type of the mandory attribute. The output emitted by this operator will be the result of the `stream` generator. This generator never fails (unless the underlying output stream reports an error). The character type of the I/O ostream is assumed to be `char`.
`stream(s)`	Call the streaming `operator<<()` for the type of the immediate value `s`. The output emitted by this operator will be the result of the `stream` generator. This generator never fails (unless the underlying output stream reports an error). The character type of the I/O ostream is assumed to be `char`.
`wstream`	Call the streaming `operator<<()` for the type of the mandory attribute. The output emitted by this operator will be the result of the `stream` generator. This generator never fails (unless the underlying output stream reports an error). The character type of the I/O ostream is assumed to be `wchar_t`.
`wstream(s)`	Call the streaming `operator<<()` for the type of the immediate value `s`. The output emitted by this operator will be the result of the `stream` generator. This generator never fails (unless the underlying output stream reports an error). The character type of the I/O ostream is assumed to be `wchar_t`.

All generators listed in the table above are predefined specializations of the `stream_generator<Char>` basic stream generator type described below. It is possible to directly use this type to create stream generators using an arbitrary underlying character type.

Expression	Semantics
`stream_generator< Char >()`	Call the streaming `operator<<()` for the type of the mandory attribute. The output emitted by this operator will be the result of the `stream` generator. This generator never fails (unless the underlying output stream reports an error). The character type of the I/O ostream is assumed to be `Char`
`stream_generator< Char >()(s)`	Call the streaming `operator<<()` for the type of the immediate value `s`. The output emitted by this operator will be the result of the `stream` generator. This generator never fails (unless the underlying output stream reports an error). The character type of the I/O ostream is assumed to be `Char`.

Additional Requirements

All of the stream generators listed above require the type of the value to generate output for (either the immediate value or the associated attribute) to implement a streaming operator conforming to the usual I/O streams conventions (where `attribute_type` is the type of the value to generate output for):

```
template <typename Ostream>
Ostream& operator<< (Ostream& os, attribute_type const& attr)
{
    // type specific output generation
    return os;
}
```

This operator will be called by the stream generators to gather the output for the attribute of type `attribute_type`. All data streamed into the given `Ostream` will end up being generated by the corresponding stream generator instance.

Note

If the `stream` generator is invoked inside a `format` (or `format_delimited`) stream manipulator the `Ostream` passed to the `operator<<()` will have registered (imbued) the same standard locale instance as the stream the `format` (or `format_delimited`) manipulator has been used with. This ensures all facets registered (imbued) with the original I/O stream object are used during output generation.

Attributes

Expression	Attribute
`stream`	`hold_any`, attribute is mandatory (otherwise compilation will fail)
`stream(s)`	`unused`
`wstream`	`hold_any`, attribute is mandatory (otherwise compilation will fail)
`wstream(s)`	`unused`
`stream_generator<Char>()`	`hold_any`, attribute is mandatory (otherwise compilation will fail)
`stream_generator<Char>()(s)`	`unused`

Important

The attribute type `hold_any` exposed by some of the stream generators is semantically and syntactically equivalent to the type implemented by Boost.Any. It has been added to *Spirit* as it has better a performance and a smaller footprint if compared to Boost.Any.

Note

In addition to their usual attribute of type `Attrib` all listed generators accept an instance of a `boost::optional<Attrib>` as well. If the `boost::optional<>` is initialized (holds a value) the generators behave as if their attribute was an instance of `Attrib` and emit the value stored in the `boost::optional<>`. Otherwise the generators will fail.

Complexity

O(N), where N is the number of characters emitted by the stream generator

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::stream;
```

And a class definition used in the examples:

```
// a simple complex number representation z = a + bi
struct complex
{
    complex (double a, double b)
      : a(a), b(b)
    {}

    double a;
    double b;
};

// define streaming operator for the type complex
std::ostream&
operator<< (std::ostream& os, complex const& z)
{
    os << "{" << z.a << "," << z.b << "}";
    return os;
}
```

Basic usage of `stream` generators:

```
test_generator_attr("abc", stream, "abc");
test_generator("abc", stream("abc"));
test_generator_attr("{1.2,2.4}", stream, complex(1.2, 2.4));
test_generator("{1.2,2.4}", stream(complex(1.2, 2.4)));
```

String

This module includes different string oriented generators allowing to output character sequences. It includes variants of the `string` generator.

Module Header

```
// forwards to <boost/spirit/home/karma/string.hpp>
#include <boost/spirit/include/karma_string.hpp>
```

Also, see Include Structure.

String (`string`, `lit`)

Description

The string generators described in this section are:

The `string` generator emits a string of characters. The `string` generator is implicitly verbatim: the `delimit` parser is not applied in between characters of the string. The `string` generator has an associated Character Encoding Namespace. This is needed when doing basic operations such as forcing lower or upper case. Examples:

```
string("Hello")
string(L"Hello")
string(s)         // s is a std::string
```

`lit`, like `string`, also emits a string of characters. The main difference is that `lit` does not consumes an attribute. A plain string like `"hello"` or a `std::basic_string` is equivalent to a `lit`. Examples:

```
"Hello"
lit("Hello")
lit(L"Hello")
lit(s)            // s is a std::string
```

Header

```
// forwards to <boost/spirit/home/karma/string/lit.hpp>
#include <boost/spirit/include/karma_string.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lit // alias: boost::spirit::karma::lit`
`ns::string`

In the table above, `ns` represents a Character Encoding Namespace used by the corresponding string generator.

Model of

`PrimitiveGenerator`

Notation

`s` Character-class specific string (See Character Class Types), or a Lazy Argument that evaluates to a character-class specific string value

`S` The type of a character-clas specific string `s`.

`ns` A Character Encoding Namespace.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveGenerator`.

Expression	Description
`s`	Generate the string literal `s`. This generator never fails (unless the underlying output stream reports an error).
`lit(s)`	Generate the string literal `s`. This generator never fails (unless the underlying output stream reports an error).
`ns::string`	Generate the string provided by a mandatory attribute interpreted in the character set defined by `ns`. This generator never fails (unless the underlying output stream reports an error).
`ns::string(s)`	Generate the string `s` as provided by the immediate literal value the generator is initialized from. If this generator has an associated attribute it succeeds only if the attribute is equal to the immediate literal (unless the underlying output stream reports an error). Otherwise this generator fails and does not generate any output.

Note

The generators `lit(s)` and `string(s)` can be initialized either using a string literal value (i.e. `"abc"`), or using a `std::basic_string<char_type, ...>`, where `char_type` is the required value type of the underlying character sequence.

Attributes

Expression	Attribute
`s`	`unused`
`lit(s)`	`unused`
`ns::string`	`S`, attribute is mandatory (otherwise compilation will fail)
`ns::string(s)`	`S`, attribute is optional, if it is supplied, the generator compares the attribute with `s` and succeeds only if both are equal, failing otherwise

Note

In addition to their usual attribute of type `S` all listed generators accept an instance of a `boost::optional<S>` as well. If the `boost::optional<>` is initialized (holds a value) the generators behave as if their attribute was an instance of `S` and emit the value stored in the `boost::optional<>`. Otherwise the generators will fail.

Complexity

O(N), where N is the number of characters emitted by the string generator

Example

Note

The test harness for the example(s) below is presented in the Basics Examples section.

Some includes:

```
#include <boost/spirit/include/karma.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/fusion/include/std_pair.hpp>
#include <iostream>
#include <string>
```

Some using declarations:

```
using boost::spirit::karma::lit;
using boost::spirit::ascii::string;
```

Basic usage of `string` generators:

```
test_generator("abc", "abc");
test_generator("abc", lit("abc"));
test_generator("abc", lit(std::string("abc")));

test_generator_attr("abc", string, "abc");
test_generator("abc", string("abc"));
test_generator("abc", string(std::string("abc")));

test_generator_attr("abc", string("abc"), "abc");
test_generator_attr("", string("abc"), "cba");     // fails (as "abc" != "cba")
```

Performance Measurements

Performance of Numeric Generators

Comparing the performance of a single int_ generator

These performance measurements are centered around default formatting of a single `int` integer number using different libraries and methods. The overall execution times for those examples are compared below. We compare using `sprintf`, C++ iostreams, Boost.Format, and *Spirit.Karma*.

For the full source code of the performance test please see here: int_generator.cpp. All the measurements have been done by executing `1e7` iterations for each formatting type (NUMITERATIONS is set to `1e7` in the code shown below).

Code used to measure the performance for `ltoa`:

```
char buffer[65]; // we don't expect more than 64 bytes to be generated here
for (int i = 0; i < MAX_ITERATION; ++i)
{
    ltoa(v[i], buffer, 10);
}
```

Code used to measure the performance for standard C++ iostreams:

```
std::stringstream str;
for (int i = 0; i < MAX_ITERATION; ++i)
{
    str.str("");
    str << v[i];
}
```

Code used to measure the performance for Boost.Format:

```
std::string str;
boost::format int_format("%d");
for (int i = 0; i < MAX_ITERATION; ++i)
{
    str = boost::str(int_format % v[i]);
}
```

Code used to measure the performance for *Spirit.Karma* using a plain character buffer:

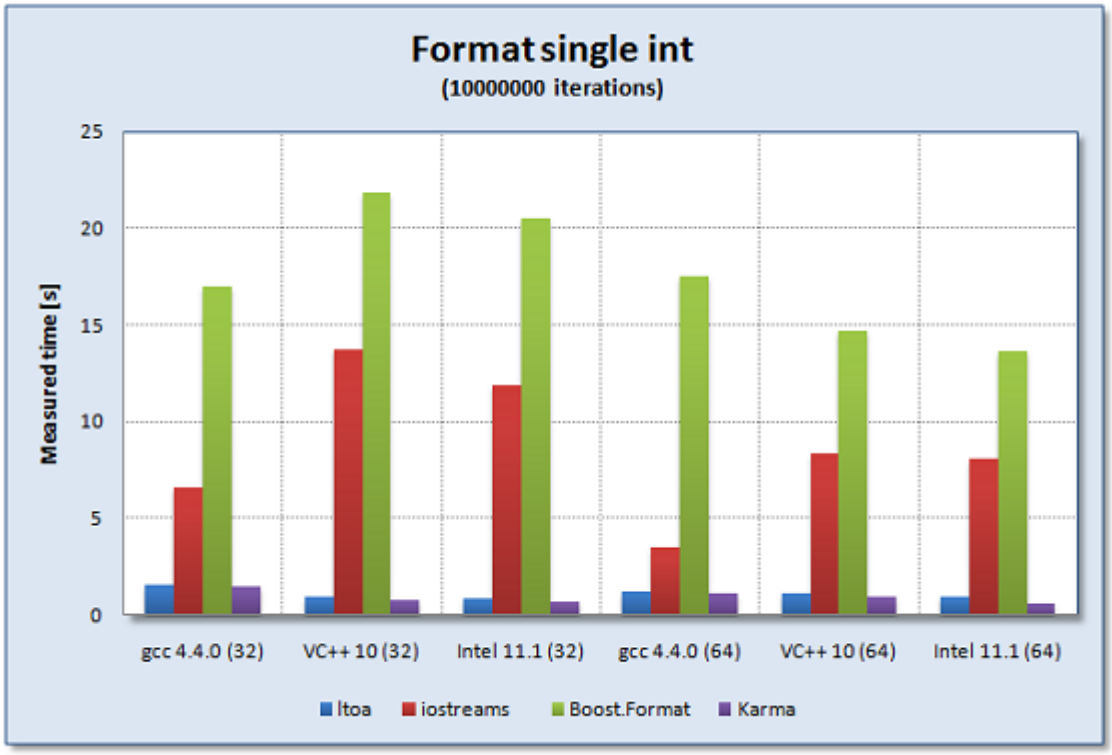
```
char buffer[65]; // we don't expect more than 64 bytes to be generated here
for (int i = 0; i < MAX_ITERATION; ++i)
{
    char *ptr = buffer;
    karma::generate(ptr, int_, v[i]);
    *ptr = '\0';
}
```

The following table shows the overall performance results collected while using different compilers. All times are in seconds measured for `1e7` iterations (platform: Windows7, Intel Core Duo(tm) Processor, 2.8GHz, 4GByte RAM). For a more readable comparison of the results see this figure.

Table 5. Performance comparison for a single int (all times in [s], `1e7` iterations)

Library	gcc 4.4.0 (32 bit)	VC++ 10 (32 bit)	Intel 11.1 (32 bit)	gcc 4.4.0 (64 bit)	VC++ 10 (64 bit)	Intel 11.1 (64 bit)
ltoa	1.542	0.895	0.884	1.163	1.099	0.906
iostreams	6.548	13.727	11.898	3.464	8.316	8.115
Boost.Format	16.998	21.813	20.477	17.464	14.662	13.646
Spirit.Karma int_	1.421	0.744	0.697	1.072	0.953	0.606

Figure 3. Performance comparison for a single int



Comparing the performance of a single double_ generator

These performance measurements are centered around default formatting of a single `double` floating point number using different libraries and methods. The overall execution times for those examples are compared below. We compare using `sprintf`, C++ iostreams, Boost.Format, and *Spirit.Karma*.

For the full source code of the performance test please see here: double_performance.cpp. All the measurements have been done by executing `1e6` iterations for each formatting type (NUMITERATIONS is set to `1e6` in the code shown below).

Code used to measure the performance for `sprintf`:

```
char buffer[256];
for (int i = 0; i < NUMITERATIONS; ++i) {
    sprintf(buffer, "%f", 12345.12345);
}
```

Code used to measure the performance for standard C++ iostreams:

```
std::stringstream strm;
for (int i = 0; i < NUMITERATIONS; ++i) {
    strm.str("");
    strm << 12345.12345;
}
```

Code used to measure the performance for Boost.Format:

```
std::string generated;
boost::format double_format("%f");
for (int i = 0; i < NUMITERATIONS; ++i)
    generated = boost::str(double_format % 12345.12345);
```

The following code shows the common definitions used by all *Spirit.Karma* performance measurements as listed below:

```
using boost::spirit::karma::double_;
```

Code used to measure the performance for *Spirit.Karma* using a plain character buffer:

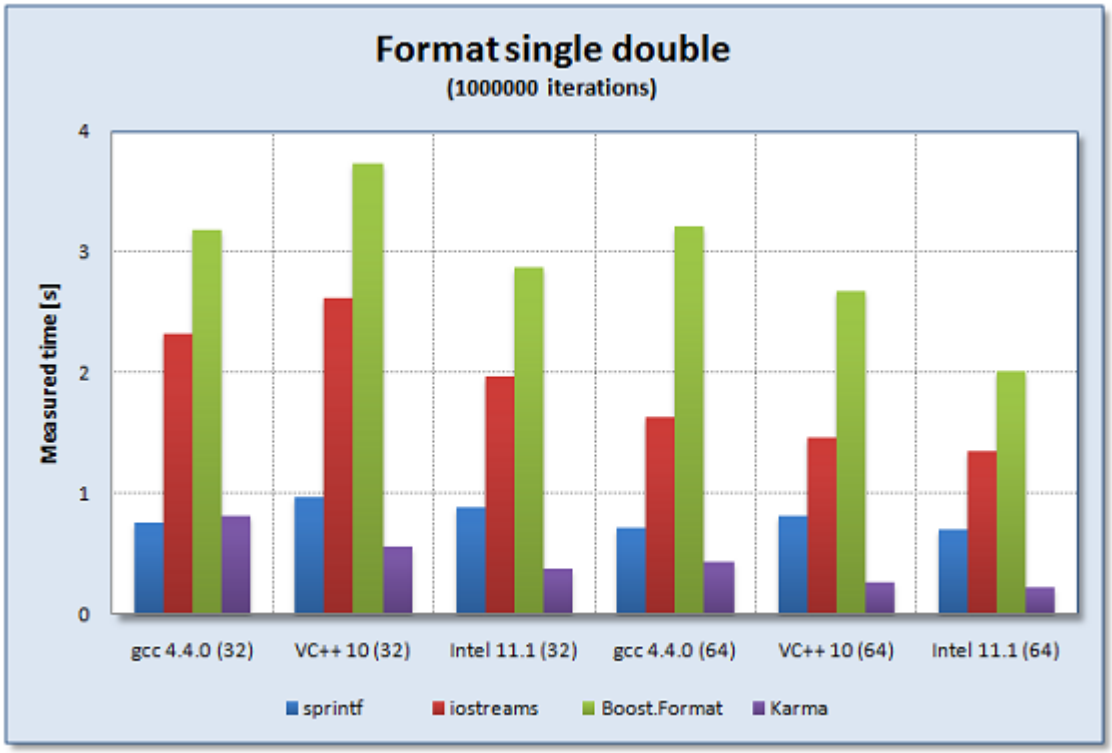
```
char buffer[256];
for (int i = 0; i < NUMITERATIONS; ++i) {
    char *p = buffer;
    generate(p, double_, 12345.12345);
    *p = '\0';
}
```

The following table shows the overall performance results collected while using different compilers. All times are in seconds measured for `1e6` iterations (platform: Windows7, Intel Core Duo(tm) Processor, 2.8GHz, 4GByte RAM). For a more readable comparison of the results see this figure.

Table 6. Performance comparison for a single double (all times in [s], `1e6` iterations)

Library	gcc 4.4.0 (32 bit)	VC++ 10 (32 bit)	Intel 11.1 (32 bit)	gcc 4.4.0 (64 bit)	VC++ 10 (64 bit)	Intel 11.1 (64 bit)
sprintf	0.755	0.965	0.880	0.713	0.807	0.694
iostreams	2.316	2.624	1.964	1.634	1.468	1.354
Boost.Format	3.188	3.737	2.878	3.217	2.672	2.011
Spirit.Karma double_	0.813	0.561	0.368	0.426	0.260	0.218

Figure 4. Performance comparison for a single double



Comparing the performance of a sequence of several generators

These performance measurements are centered around formatting of a sequence of different items, including 2 `double` floating point numbers using different libraries and methods. The overall execution times for those examples are compared below. We compare using `sprintf`, C++ iostreams, Boost.Format, and *Spirit.Karma*.

For the full source code of the performance test please see here: format_performance.cpp. All the measurements have been done by doing `1e6` iterations for each formatting type (NUMITERATIONS is set to `1e6`).

Code used to measure the performance for sprintf:

```
char buffer[256];
for (int i = 0; i < NUMITERATIONS; ++i) {
    sprintf(buffer, "[%-14.3f%-14.3f]", 12345.12345, 12345.12345);
}
```

Code used to measure the performance for standard iostreams:

```
std::stringstream strm;
for (int i = 0; i < NUMITERATIONS; ++i) {
    strm.str("");
    strm << '['
      << std::setiosflags(std::ios::fixed)
      << std::left
      << std::setprecision(3)
      << std::setw(14)
      << 12345.12345
      << std::setw(14)
      << 12345.12345
      << ']';
}
```

Code used to measure the performance for Boost.Format:

```
std::string generated;
boost::format outformat("[%-14.3f%-14.3f]");
for (int i = 0; i < NUMITERATIONS; ++i)
    generated = boost::str(outformat % 12345.12345 % 12345.12345);
```

The following code shows the common definitions used by all *Spirit.Karma* performance measurements as listed below:

```
template <typename T>
struct double3_policy : boost::spirit::karma::real_policies<T>
{
    //  we want to generate up to 3 fractional digits
    static unsigned int precision(T) { return 3; }
};

typedef boost::spirit::karma::real_generator<double, double3_policy<double> >
    double3_type;
double3_type const double3 = double3_type();
```

Code used to measure the performance for *Spirit.Karma* using a plain character buffer:

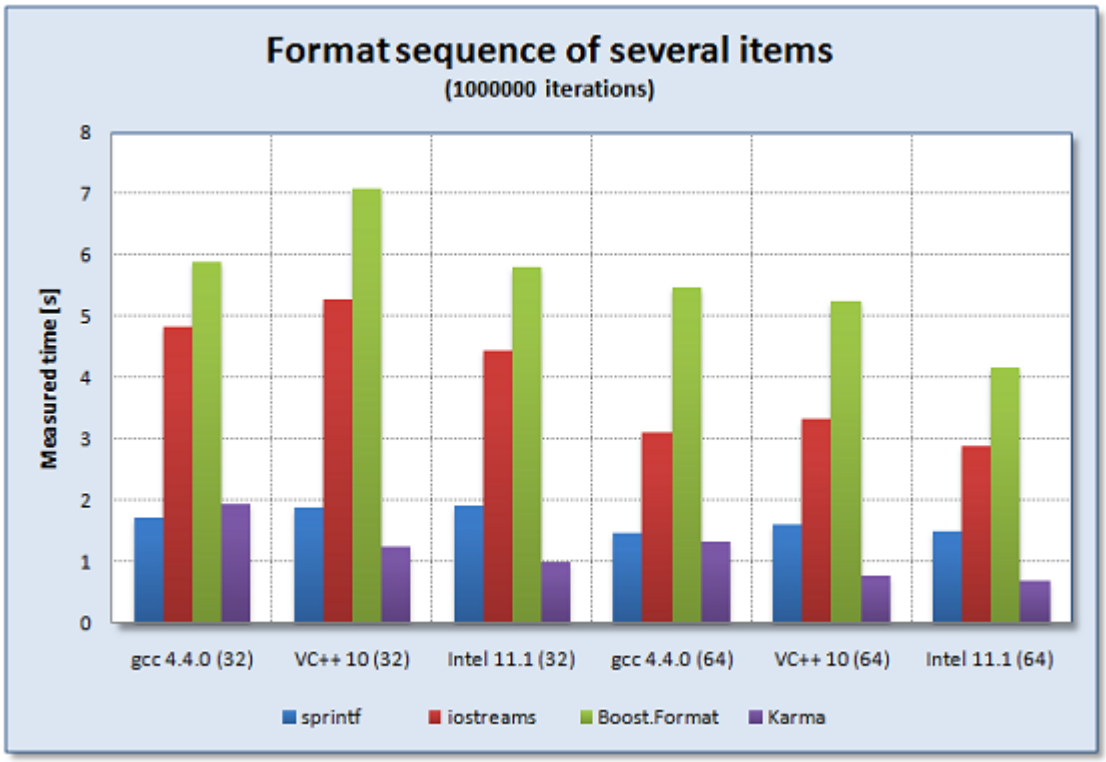
```
char buffer[256];
for (int i = 0; i < NUMITERATIONS; ++i) {
    char *p = buffer;
    generate(p
      , '[' << left_align(14)[double3] << left_align(14)[double3] << ']'
      , 12345.12345, 12345.12345);
    *p = '\0';
}
```

The following table shows the overall performance results collected while using different compilers. All times are in seconds measured for `1e6` iterations (platform: Windows7, Intel Core Duo(tm) Processor, 2.8GHz, 4GByte RAM). For a more readable comparison of the results see this figure.

Table 7. Performance comparison for a sequence of several items (all times in [s], `1e6` iterations)

Library	gcc 4.4.0 (32 bit)	VC++ 10 (32 bit)	Intel 11.1 (32 bit)	gcc 4.4.0 (64 bit)	VC++ 10 (64 bit)	Intel 11.1 (64 bit)
sprintf	1.725	1.892	1.903	1.469	1.608	1.493
iostreams	4.827	5.287	4.444	3.112	3.319	2.877
Boost.Format	5.881	7.089	5.801	5.455	5.254	4.164
Spirit.Karma	1.942	1.242	0.999	1.334	0.758	0.686

Figure 5. Performance comparison for a sequence of several items



Lex - Writing Lexical Analyzers

Introduction to *Spirit.Lex*

Lexical scanning is the process of analyzing the stream of input characters and separating it into strings called tokens, separated by whitespace. Most compiler texts start here, and devote several chapters to discussing various ways to build scanners. *Spirit.Lex* is a library built to take care of the complexities of creating a lexer for your grammar (in this documentation we will use the terms 'lexical analyzer', 'lexer' and 'scanner' interchangably). All that is needed to create a lexer is to know the set of patterns describing the different tokens you want to recognize in the input. To make this a bit more formal, here are some definitions:

- A token is a sequence of consecutive characters having a collective meaning. Tokens may have attributes specific to the token type, carrying additional information about the matched character sequence.
- A pattern is a rule expressed as a regular expression and describing how a particular token can be formed. For example, `[A-Za-z][A-Za-z_0-9]*` is a pattern for a rule matching C++ identifiers.

- Characters between tokens are called whitespace; these include spaces, tabs, newlines, and formfeeds. Many people also count comments as whitespace, though since some tools such as lint look at comments, this method is not perfect.

Why Use a Separate Lexer?

Typically, lexical scanning is done in a separate module from the parser, feeding the parser with a stream of input tokens only. Theoretically it is not necessary implement this separation as in the end there is only one set of syntactical rules defining the language, so in theory we could write the whole parser in one module. In fact, *Spirit.Qi* allows you to write parsers without using a lexer, parsing the input character stream directly, and for the most part this is the way Spirit has been used since its invention.

However, this separation has both practical and theoretical basis, and proves to be very useful in practical applications. In 1956, Noam Chomsky defined the "Chomsky Hierarchy" of grammars:

- Type 0: Unrestricted grammars (e.g., natural languages)
- Type 1: Context-Sensitive grammars
- Type 2: Context-Free grammars
- Type 3: Regular grammars

The complexity of these grammars increases from regular grammars being the simplest to unrestricted grammars being the most complex. Similarly, the complexity of pattern recognition for these grammars increases. Although, a few features of some programming languages (such as C++) are Type 1, fortunately for the most part programming languages can be described using only the Types 2 and 3. The neat part about these two types is that they are well known and the ways to parse them are well understood. It has been shown that any regular grammar can be parsed using a state machine (finite automaton). Similarly, context-free grammars can always be parsed using a push-down automaton (essentially a state machine augmented by a stack).

In real programming languages and practical grammars, the parts that can be handled as regular expressions tend to be the lower-level pieces, such as the definition of an identifier or of an integer value:

```
letter     := [a-zA-Z]
digit      := [0-9]

identifier := letter [ letter | digit ]*
integer    := digit+
```

Higher level parts of practical grammars tend to be more complex and can't be implemented using plain regular expressions. We need to store information on the built-in hardware stack while recursing the grammar hierarchy, and that is the preferred approach used for top-down parsing. Since it takes a different kind of abstract machine to parse the two types of grammars, it proved to be efficient to separate the lexical scanner into a separate module which is built around the idea of a state machine. The goal here is to use the simplest parsing technique needed for the job.

Another, more practical, reason for separating the scanner from the parser is the need for backtracking during parsing. The input data is a stream of characters, which is often thought to be processed left to right without any backtracking. Unfortunately, in practice most of the time that isn't possible. Almost every language has certain keywords such as IF, FOR, and WHILE. The decision if a certain character sequence actually comprises a keyword or just an identifier often can be made only after seeing the first delimiter *after* it. In fact, this makes the process backtracking, since we need to store the string long enough to be able to make the decision. The same is true for more coarse grained language features such as nested IF/ELSE statements, where the decision about to which IF belongs the last ELSE statement can be made only after seeing the whole construct.

So the structure of a conventional compiler often involves splitting up the functions of the lower-level and higher-level parsing. The lexical scanner deals with things at the character level, collecting characters into strings, converting character sequence into different representations as integers, etc., and passing them along to the parser proper as indivisible tokens. It's also considered normal to let the scanner do additional jobs, such as identifying keywords, storing identifiers in tables, etc.

Now, Spirit follows this structure, where *Spirit.Lex* can be used to implement state machine based recognizers, while *Spirit.Qi* can be used to build recognizers for context free grammars. Since both modules are seemlessly integrated with each other and with the C++ target language it is even possible to use the provided functionality to build more complex grammar recognizers.

Advantages of using *Spirit.Lex*

The advantage of using *Spirit.Lex* to create the lexical analyzer over using more traditional tools such as Flex is its carefully crafted integration with the Spirit library and the C++ host language. You don't need any external tools to generate the code, your lexer will be perfectly integrated with the rest of your program, making it possible to freely access any context information and data structure. Since the C++ compiler sees all the code, it will generate optimal code no matter what configuration options have been chosen by the user. *Spirit.Lex* gives you the vast majority of features you could get from a similar Flex program without the need to leave C++ as a host language:

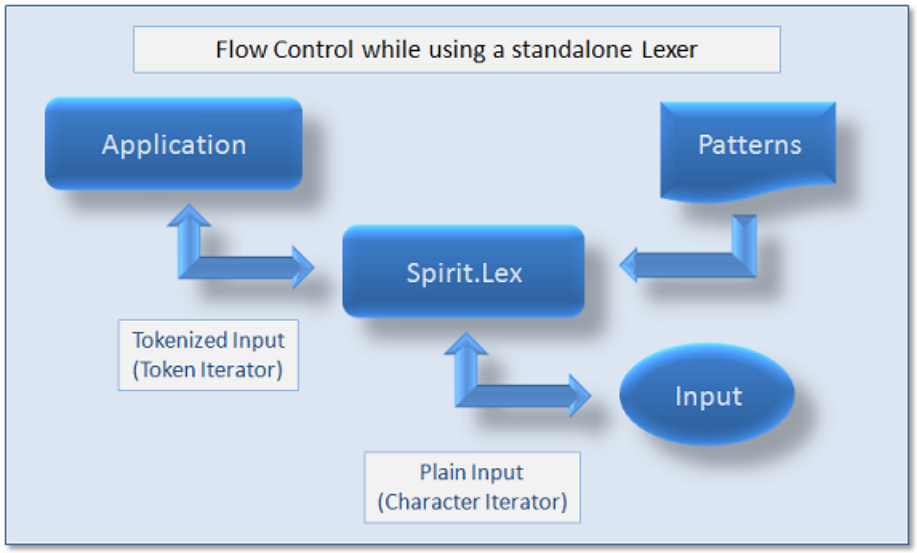
- The definition of tokens is done using regular expressions (patterns)
- The token definitions can refer to special substitution strings (pattern macros) simplifying pattern definitions
- The generated lexical scanner may have multiple start states
- It is possible to attach code to any of the token definitions; this code gets executed whenever the corresponding token pattern has been matched

Even if it is possible to use *Spirit.Lex* to generate C++ code representing the lexical analyzer (we will refer to that as the *static* model, described in more detail in the section The *Static* Model) - a model very similar to the way Flex operates - we will mainly focus on the opposite, the *dynamic* model. You can directly integrate the token definitions into your C++ program, building the lexical analyzer dynamically at runtime. The dynamic model is something not supported by Flex or other lexical scanner generators (such as re2c, Ragel, etc.). This dynamic flexibility allows you to speed up the development of your application.

The Library Structure of *Spirit.Lex*

The figure below shows a high level overview of how the *Spirit.Lex* library might be used in an application. *Spirit.Lex* allows to create lexical analyzers based on patterns. These patterns are regular expression based rules used to define the different tokens to be recognized in the character input sequence. The input sequence is expected to be provided to the lexical analyzer as an arbitrary standard forward iterator. The lexical analyzer itself exposes a standard forward iterator as well. The difference here is that the exposed iterator provides access to the token sequence instead of to the character sequence. The tokens in this sequence are constructed on the fly by analyzing the underlying character sequence and matching this to the patterns as defined by the application.

Figure 6. The Library structure and Common Flow of Information while using *Spirit.Lex* in an application



Spirit.Lex Tutorials

Spirit.Lex Tutorials Overview

The *Spirit.Lex* library implements several components on top of possibly different lexer generator libraries. It exposes a pair of iterators, which, when dereferenced, return a stream of tokens generated from the underlying character stream. The generated tokens are based on the token definitions supplied by the user.

Currently, *Spirit.Lex* is built on top of Ben Hansons excellent Lexertl library (which is a proposed Boost library). Lexertl provides the necessary functionality to build state machines based on a set of supplied regular expressions. But *Spirit.Lex* is not restricted to be used with Lexertl. We expect it to be usable in conjunction with any other lexical scanner generator library, all what needs to be implemented is a set of wrapper objects exposing a well defined interface as described in this documentation.

Note

For the sake of clarity all examples in this documentation assume *Spirit.Lex* to be used on top of Lexertl.

Building a lexer using *Spirit.Lex* is highly configurable, where most of this configuration is done at compile time. Almost all of the configurable parameters have generally useful default values, allowing project startup to be a easy and straightforward task. Here is a (non-complete) list of features you can tweak to adjust the generated lexer instance to the actual needs:

- Select and customize the token type to be generated by the lexer instance.
- Select and customize the token value types the generated token instances will be able to hold.
- Select the iterator type of the underlying input stream, which will be used as the source for the character stream to tokenize.
- Customize the iterator type returned by the lexer to enable debug support, special handling of certain input sequences, etc.
- Select the *dynamic* or the *static* runtime model for the lexical analyzer.

Special care has been taken during the development of the library that optimal code will be generated regardless of the configuration options selected.

The series of tutorial examples of this section will guide you through some common use cases helping to understand the big picture. The first two quick start examples (Lex Quickstart 1 - A word counter using *Spirit.Lex* and Lex Quickstart 2 - A better word counter using *Spirit.Lex*) introduce the *Spirit.Lex* library while building two standalone applications, not being connected to or depending on any other part of Spirit. The section Lex Quickstart 3 - Counting Words Using a Parser demonstrates how to use a lexer in conjunction with a parser (where obviously the parser is built using *Spirit.Qi*).

Quickstart 1 - A word counter using *Spirit.Lex*

Spirit.Lex is very modular, which follows the general building principle of the Spirit libraries. You never pay for features you don't use. It is nicely integrated with the other parts of Spirit but nevertheless can be used separately to build standalone lexical analyzers. The first quick start example describes a standalone application: counting characters, words, and lines in a file, very similar to what the well known Unix command `wc` is doing (for the full example code see here: word_count_functor.cpp).

Prerequisites

The only required `#include` specific to *Spirit.Lex* follows. It is a wrapper for all necessary definitions to use *Spirit.Lex* in a standalone fashion, and on top of the Lexertl library. Additionally we `#include` two of the Boost headers to define `boost::bind()` and `boost::ref()`.

```
#include <boost/spirit/include/lex_lexertl.hpp>
#include <boost/bind.hpp>
#include <boost/ref.hpp>
```

To make all the code below more readable we introduce the following namespaces.

```
namespace lex = boost::spirit::lex;
```

Defining Tokens

The most important step while creating a lexer using *Spirit.Lex* is to define the tokens to be recognized in the input sequence. This is normally done by defining the regular expressions describing the matching character sequences, and optionally their corresponding token ids. Additionally the defined tokens need to be associated with an instance of a lexer object as provided by the library. The following code snippet shows how this can be done using *Spirit.Lex*.

The template `word_count_tokens` defines three different tokens: `ID_WORD`, `ID_EOL`, and `ID_CHAR`, representing a word (anything except a whitespace or a newline), a newline character, and any other character (`ID_WORD`, `ID_EOL`, and `ID_CHAR` are enum values representing the token ids, but could be anything else convertible to an integer as well). The direct base class of any token definition class needs to be the template `lex::lexer<>`, where the corresponding template parameter (here: `lex::lexertl::lexer<BaseIterator>`) defines which underlying lexer engine has to be used to provide the required state machine functionality. In this example we use the Lexertl based lexer engine as the underlying lexer type.

```
template <typename Lexer>
struct word_count_tokens : lex::lexer<Lexer>
{
    word_count_tokens()
    {
        // define tokens (the regular expression to match and the corresponding
        // token id) and add them to the lexer
        this->self.add
            ("[^ \t\n]+", ID_WORD) // words (anything except ' ', '\t' or '\n')
            ("\n", ID_EOL)         // newline characters
            (".", ID_CHAR)         // anything else is a plain character
        ;
    }
};
```

Doing the Useful Work

We will use a setup, where we want the *Spirit.Lex* library to invoke a given function after any of of the generated tokens is recognized. For this reason we need to implement a functor taking at least the generated token as an argument and returning a boolean value allowing to stop the tokenization process. The default token type used in this example carries a token value of the type `boost::iterator_range<BaseIterator>` pointing to the matched range in the underlying input sequence.

In this example the struct 'counter' is used as a functor counting the characters, words and lines in the analyzed input sequence by identifying the matched tokens as passed from the *Spirit.Lex* library.

```
struct counter
{
    // the function operator gets called for each of the matched tokens
    // c, l, w are references to the counters used to keep track of the numbers
    template <typename Token>
    bool operator()(Token const& t, std::size_t& c, std::size_t& w, std::size_t& l) const
    {
        switch (t.id()) {
        case ID_WORD:       // matched a word
        // since we're using a default token type in this example, every
        // token instance contains a `iterator_range<BaseIterator>` as its token
        // attribute pointing to the matched character sequence in the input
            ++w; c += t.value().size();
            break;
        case ID_EOL:        // matched a newline character
            ++l; ++c;
            break;
        case ID_CHAR:       // matched something else
            ++c;
            break;
        }
        return true;        // always continue to tokenize
    }
};
```

All what is left is to write some boilerplate code helping to tie together the pieces described so far. To simplify this example we call the `lex::tokenize()` function implemented in *Spirit.Lex* (for a more detailed description of this function see here: **FIXME**), even if we could have written a loop to iterate over the lexer iterators [`first`, `last`) as well.

Pulling Everything Together

The main function simply loads the given file into memory (as a `std::string`), instantiates an instance of the token definition template using the correct iterator type (`word_count_tokens<char const*>`), and finally calls `lex::tokenize`, passing an instance of the counter function object. The return value of `lex::tokenize()` will be `true` if the whole input sequence has been successfully tokenized, and `false` otherwise.

```
int main(int argc, char* argv[])
{
    // these variables are used to count characters, words and lines
    std::size_t c = 0, w = 0, l = 0;

    // read input from the given file
    std::string str (read_from_file(1 == argc ? "word_count.input" : argv[1]));

    // create the token definition instance needed to invoke the lexical analyzer
    word_count_tokens<lex::lexertl::lexer<> > word_count_functor;

    // tokenize the given string, the bound functor gets invoked for each of
    // the matched tokens
    char const* first = str.c_str();
    char const* last = &first[str.size()];
    bool r = lex::tokenize(first, last, word_count_functor,
        boost::bind(counter(), _1, boost::ref(c), boost::ref(w), boost::ref(l)));

    // print results
    if (r) {
        std::cout << "lines: " << l << ", words: " << w
                  << ", characters: " << c << "\n";
    }
    else {
        std::string rest(first, last);
        std::cout << "Lexical analysis failed\n" << "stopped at: \""
                  << rest << "\"\n";
    }
    return 0;
}
```

Comparing *Spirit.Lex* with Flex

This example was deliberately chosen to be as much as possible similar to the equivalent Flex program (see below), which isn't too different from what has to be written when using *Spirit.Lex*.

Note

Interestingly enough, performance comparisons of lexical analyzers written using *Spirit.Lex* with equivalent programs generated by Flex show that both have comparable execution speeds! Generally, thanks to the highly optimized Lexertl library and due its carefully designed integration with Spirit the abstraction penalty to be paid for using *Spirit.Lex* is neglectible.

The remaining examples in this tutorial will use more sophisticated features of *Spirit.Lex*, mainly to allow further simplification of the code to be written, while maintaining the similarity with corresponding features of Flex. *Spirit.Lex* has been designed to be as similiar to Flex as possible. That is why this documentation will provide the corresponding Flex code for the shown *Spirit.Lex* examples almost everywhere. So consequently, here is the Flex code corresponding to the example as shown above.

```
%{
    #define ID_WORD 1000
    #define ID_EOL  1001
    #define ID_CHAR 1002
    int c = 0, w = 0, l = 0;
%}
%%
[^ \t\n]+  { return ID_WORD; }
\n         { return ID_EOL; }
.          { return ID_CHAR; }
%%
bool count(int tok)
{
    switch (tok) {
    case ID_WORD: ++w; c += yyleng; break;
    case ID_EOL:  ++l; ++c; break;
    case ID_CHAR: ++c; break;
    default:
        return false;
    }
    return true;
}
void main()
{
    int tok = EOF;
    do {
        tok = yylex();
        if (!count(tok))
            break;
    } while (EOF != tok);
    printf("%d %d %d\n", l, w, c);
}
```

Quickstart 2 - A better word counter using *Spirit.Lex*

People familiar with Flex will probably complain about the example from the section Lex Quickstart 1 - A word counter using *Spirit.Lex* as being overly complex and not being written to leverage the possibilities provided by this tool. In particular the previous example did not directly use the lexer actions to count the lines, words, and characters. So the example provided in this step of the tutorial will show how to use semantic actions in *Spirit.Lex*. Even though this examples still counts textual elements, the purpose is to introduce new concepts and configuration options along the lines (for the full example code see here: word_count_lexer.cpp).

Prerequisites

In addition to the only required `#include` specific to *Spirit.Lex* this example needs to include a couple of header files from the Boost.Phoenix library. This example shows how to attach functors to token definitions, which could be done using any type of C++ technique resulting in a callable object. Using Boost.Phoenix for this task simplifies things and avoids adding dependencies to other libraries (Boost.Phoenix is already in use for Spirit anyway).

```
#include <boost/spirit/include/lex_lexertl.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/spirit/include/phoenix_statement.hpp>
#include <boost/spirit/include/phoenix_algorithm.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
```

To make all the code below more readable we introduce the following namespaces.

```
namespace lex = boost::spirit::lex;
```

To give a preview at what to expect from this example, here is the flex program which has been used as the starting point. The useful code is directly included inside the actions associated with each of the token definitions.

```
%{
    int c = 0, w = 0, l = 0;
%}
%%
[^ \t\n]+  { ++w; c += yyleng; }
\n         { ++c; ++l; }
.          { ++c; }
%%
main()
{
    yylex();
    printf("%d %d %d\n", l, w, c);
}
```

Semantic Actions in *Spirit.Lex*

Spirit.Lex uses a very similar way of associating actions with the token definitions (which should look familiar to anybody knowledgeable with Spirit as well): specifying the operations to execute inside of a pair of `[]` brackets. In order to be able to attach semantic actions to token definitions for each of them there is defined an instance of a `token_def<>`.

```
template <typename Lexer>
struct word_count_tokens : lex::lexer<Lexer>
{
    word_count_tokens()
      : c(0), w(0), l(0)
      , word("[^ \t\n]+")     // define tokens
      , eol("\n")
      , any(".")
    {
        using boost::spirit::lex::_start;
        using boost::spirit::lex::_end;
        using boost::phoenix::ref;

        // associate tokens with the lexer
        this->self
            =   word  [++ref(w), ref(c) += distance(_start, _end)]
            |   eol   [++ref(c), ++ref(l)]
            |   any   [++ref(c)]
            ;
    }

    std::size_t c, w, l;
    lex::token_def<> word, eol, any;
};
```

The semantics of the shown code is as follows. The code inside the `[]` brackets will be executed whenever the corresponding token has been matched by the lexical analyzer. This is very similar to Flex, where the action code associated with a token definition gets executed after the recognition of a matching input sequence. The code above uses function objects constructed using Boost.Phoenix, but it is possible to insert any C++ function or function object as long as it exposes the proper interface. For more details on please refer to the section Lexer Semantic Actions.

Associating Token Definitions with the Lexer

If you compare this code to the code from Lex Quickstart 1 - A word counter using *Spirit.Lex* with regard to the way how token definitions are associated with the lexer, you will notice a different syntax being used here. In the previous example we have been

using the `self.add()` style of the API, while we here directly assign the token definitions to `self`, combining the different token definitions using the `|` operator. Here is the code snippet again:

```
this->self
    =   word  [++ref(w), ref(c) += distance(_1)]
    |   eol   [++ref(c), ++ref(l)]
    |   any   [++ref(c)]
    ;
```

This way we have a very powerful and natural way of building the lexical analyzer. If translated into English this may be read as: The lexical analyer will recognize ('=') tokens as defined by any of ('|') the token definitions `word`, `eol`, and `any`.

A second difference to the previous example is that we do not explicitly specify any token ids to use for the separate tokens. Using semantic actions to trigger some useful work has freed us from the need to define those. To ensure every token gets assigned a id the *Spirit.Lex* library internally assigns unique numbers to the token definitions, starting with the constant defined by `boost::spirit::lex::min_token_id`.

Pulling everything together

In order to execute the code defined above we still need to instantiate an instance of the lexer type, feed it from some input sequence and create a pair of iterators allowing to iterate over the token sequence as created by the lexer. This code shows how to achieve these steps:

```
int main(int argc, char* argv[])
{

❶  typedef
       lex::lexertl::token<char const*, lex::omit, boost::mpl::false_>
    token_type;

❷  typedef lex::lexertl::actor_lexer<token_type> lexer_type;

❸  word_count_tokens<lexer_type> word_count_lexer;

❹  std::string str (read_from_file(1 == argc ? "word_count.input" : argv[1]));
    char const* first = str.c_str();
    char const* last = &first[str.size()];

❺  lexer_type::iterator_type iter = word_count_lexer.begin(first, last);
    lexer_type::iterator_type end = word_count_lexer.end();

❻  while (iter != end && token_is_valid(*iter))
       ++iter;

    if (iter == end) {
        std::cout << "lines: " << word_count_lexer.l
                  << ", words: " << word_count_lexer.w
                  << ", characters: " << word_count_lexer.c
                  << "\n";
    }
    else {
        std::string rest(first, last);
        std::cout << "Lexical analysis failed\n" << "stopped at: \""
                  << rest << "\"\n";
    }
    return 0;
}
```

❶ Specifying `omit` as the token attribute type generates a token class not holding any token attribute at all (not even the iterator range of the matched input sequence), therefore optimizing the token, the lexer, and possibly the parser implementation as

much as possible. Specifying `mpl::false_` as the 3rd template parameter generates a token type and an iterator, both holding no lexer state, allowing for even more aggressive optimizations. As a result the token instances contain the token ids as the only data member.

❷ This defines the lexer type to use

❸ Create the lexer object instance needed to invoke the lexical analysis

❹ Read input from the given file, tokenize all the input, while discarding all generated tokens

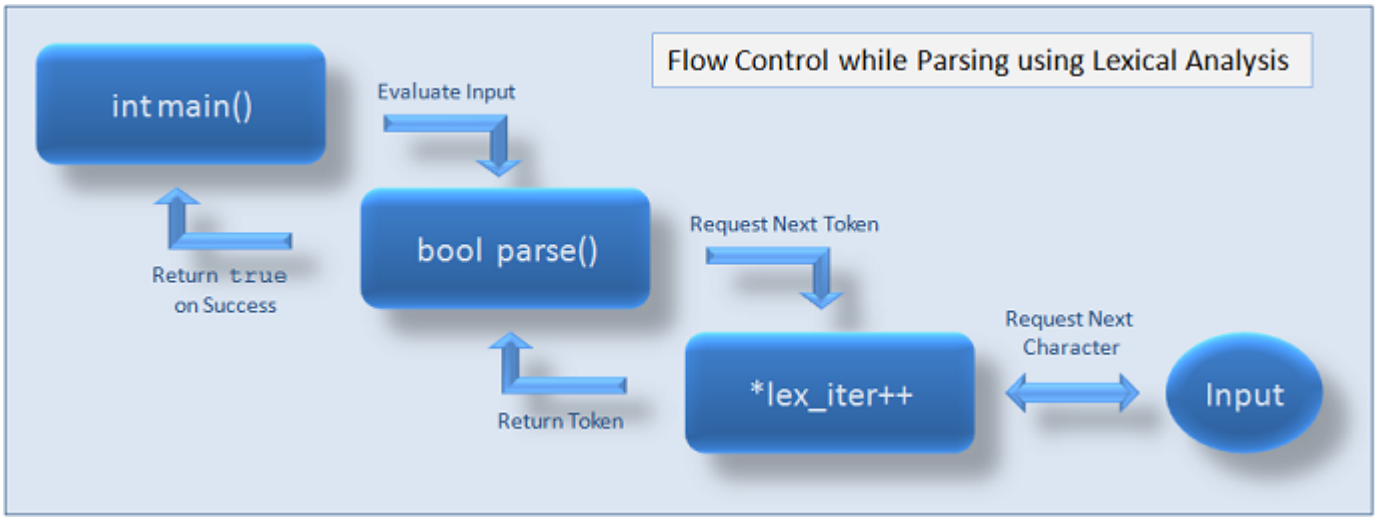
❺ Create a pair of iterators returning the sequence of generated tokens

❻ Here we simply iterate over all tokens, making sure to break the loop if an invalid token gets returned from the lexer

Quickstart 3 - Counting Words Using a Parser

The whole purpose of integrating *Spirit.Lex* as part of the Spirit library was to add a library allowing the merger of lexical analysis with the parsing process as defined by a Spirit grammar. Spirit parsers read their input from an input sequence accessed by iterators. So naturally, we chose iterators to be used as the interface beween the lexer and the parser. A second goal of the lexer/parser integration was to enable the usage of different lexical analyzer libraries. The utilization of iterators seemed to be the right choice from this standpoint as well, mainly because these can be used as an abstraction layer hiding implementation specifics of the used lexer library. The picture below shows the common flow control implemented while parsing combined with lexical analysis.

Figure 7. The common flow control implemented while parsing combined with lexical analysis



Another problem related to the integration of the lexical analyzer with the parser was to find a way how the defined tokens syntactically could be blended with the grammar definition syntax of Spirit. For tokens defined as instances of the `token_def<>` class the most natural way of integration was to allow to directly use these as parser components. Semantically these parser components succeed matching their input whenever the corresponding token type has been matched by the lexer. This quick start example will demonstrate this (and more) by counting words again, simply by adding up the numbers inside of semantic actions of a parser (for the full example code see here: word_count.cpp).

Prerequisites

This example uses two of the Spirit library components: *Spirit.Lex* and *Spirit.Qi*, consequently we have to `#include` the corresponding header files. Again, we need to include a couple of header files from the Boost.Phoenix library. This example shows how to attach functors to parser components, which could be done using any type of C++ technique resulting in a callable object. Using Boost.Phoenix for this task simplifies things and avoids adding dependencies to other libraries (Boost.Phoenix is already in use for Spirit anyway).

```
#include <boost/spirit/include/qi.hpp>
#include <boost/spirit/include/lex_lexertl.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <boost/spirit/include/phoenix_statement.hpp>
#include <boost/spirit/include/phoenix_container.hpp>
```

To make all the code below more readable we introduce the following namespaces.

```
using namespace boost::spirit;
using namespace boost::spirit::ascii;
```

Defining Tokens

If compared to the two previous quick start examples (Lex Quickstart 1 - A word counter using *Spirit.Lex* and Lex Quickstart 2 - A better word counter using *Spirit.Lex*) the token definition class for this example does not reveal any surprises. However, it uses lexer token definition macros to simplify the composition of the regular expressions, which will be described in more detail in the section **FIXME**. Generally, any token definition is usable without modification from either a standalone lexical analyzer or in conjunction with a parser.

```
template <typename Lexer>
struct word_count_tokens : lex::lexer<Lexer>
{
    word_count_tokens()
    {
        // define patterns (lexer macros) to be used during token definition
        // below
        this->self.add_pattern
            ("WORD", "[^ \t\n]+")
        ;

        // define tokens and associate them with the lexer
        word = "{WORD}";    // reference the pattern 'WORD' as defined above

        // this lexer will recognize 3 token types: words, newlines, and
        // everything else
        this->self.add
            (word)          // no token id is needed here
            ('\n')          // characters are usable as tokens as well
            (".", IDANY)    // string literals will not be esacped by the library
        ;
    }

    // the token 'word' exposes the matched string as its parser attribute
    lex::token_def<std::string> word;
};
```

Using Token Definition Instances as Parsers

While the integration of lexer and parser in the control flow is achieved by using special iterators wrapping the lexical analyzer, we still need a means of expressing in the grammar what tokens to match and where. The token definition class above uses three different ways of defining a token:

- Using an instance of a `token_def<>`, which is handy whenever you need to specify a token attribute (for more information about lexer related attributes please look here: Lexer Attributes).
- Using a single character as the token, in this case the character represents itself as a token, where the token id is the ASCII character value.
- Using a regular expression represented as a string, where the token id needs to be specified explicitly to make the token accessible from the grammar level.

All three token definition methods require a different method of grammar integration. But as you can see from the following code snippet, each of these methods are straightforward and blend the corresponding token instances naturally with the surrounding *Spirit.Qi* grammar syntax.

Token definition	Parser integration
`token_def<>`	The `token_def<>` instance is directly usable as a parser component. Parsing of this component will succeed if the regular expression used to define this has been matched successfully.
single character	The single character is directly usable in the grammar. However, under certain circumstances it needs to be wrapped by a `char_()` parser component. Parsing of this component will succeed if the single character has been matched.
explicit token id	To use an explicit token id in a *Spirit.Qi* grammar you are required to wrap it with the special `token()` parser component. Parsing of this component will succeed if the current token has the same token id as specified in the expression `token(<id>)`.

The grammar definition below uses each of the three types demonstrating their usage.

```
template <typename Iterator>
struct word_count_grammar : qi::grammar<Iterator>
{
    template <typename TokenDef>
    word_count_grammar(TokenDef const& tok)
      : word_count_grammar::base_type(start)
      , c(0), w(0), l(0)
    {
        using boost::phoenix::ref;
        using boost::phoenix::size;

        start =  *(   tok.word          [++ref(w), ref(c) += size(_1)]
                  |   lit('\n')         [++ref(c), ++ref(l)]
                  |   qi::token(IDANY)  [++ref(c)]
                  )
              ;
    }

    std::size_t c, w, l;
    qi::rule<Iterator> start;
};
```

As already described (see: Attributes), the *Spirit.Qi* parser library builds upon a set of of fully attributed parser components. Consequently, all token definitions support this attribute model as well. The most natural way of implementing this was to use the token values as the attributes exposed by the parser component corresponding to the token definition (you can read more about this topic here: About Tokens and Token Values). The example above takes advantage of the full integration of the token values as the `token_def<>`'s parser attributes: the `word` token definition is declared as a `token_def<std::string>`, making every instance of a `word` token carry the string representation of the matched input sequence as its value. The semantic action attached to `tok.word` receives this string (represented by the `_1` placeholder) and uses it to calculate the number of matched characters: `ref(c) += size(_1)`.

Pulling Everything Together

The main function needs to implement a bit more logic now as we have to initialize and start not only the lexical analysis but the parsing process as well. The three type definitions (`typedef` statements) simplify the creation of the lexical analyzer and the grammar. After reading the contents of the given file into memory it calls the function `tokenize_and_parse()` to initialize the lexical analysis and parsing processes.

```
int main(int argc, char* argv[])
{
❶  typedef lex::lexertl::token<
        char const*, boost::mpl::vector<std::string>
    > token_type;

❷  typedef lex::lexertl::lexer<token_type> lexer_type;

❸  typedef word_count_tokens<lexer_type>::iterator_type iterator_type;

    // now we use the types defined above to create the lexer and grammar
    // object instances needed to invoke the parsing process
    word_count_tokens<lexer_type> word_count;          // Our lexer
    word_count_grammar<iterator_type> g (word_count);  // Our parser

    // read in the file int memory
    std::string str (read_from_file(1 == argc ? "word_count.input" : argv[1]));
    char const* first = str.c_str();
    char const* last = &first[str.size()];

❹  bool r = lex::tokenize_and_parse(first, last, word_count, g);

    if (r) {
        std::cout << "lines: " << g.l << ", words: " << g.w
                  << ", characters: " << g.c << "\n";
    }
    else {
        std::string rest(first, last);
        std::cerr << "Parsing failed\n" << "stopped at: \""
                  << rest << "\"\n";
    }
    return 0;
}
```

❶ Define the token type to be used: `std::string` is available as the type of the token attribute
❷ Define the lexer type to use implementing the state machine
❸ Define the iterator type exposed by the lexer type
❹ Parsing is done based on the the token stream, not the character stream read from the input. The function `tokenize_and_parse()` wraps the passed iterator range `[first, last)` by the lexical analyzer and uses its exposed iterators to parse the toke stream.

Abstracts

Lexer Primitives

About Tokens and Token Values

As already discussed, lexical scanning is the process of analyzing the stream of input characters and separating it into strings called tokens, most of the time separated by whitespace. The different token types recognized by a lexical analyzer often get assigned unique integer token identifiers (token ids). These token ids are normally used by the parser to identifiy the current token without having to look at the matched string again. The *Spirit.Lex* library is not different with respect to this, as it uses the token ids as the main means of identification of the different token types defined for a particular lexical analyzer. However, it is different from commonly used lexical analyzers in the sense that it returns (references to) instances of a (user defined) token class to the user. The only limitation of this token class is that it must carry at least the token id of the token it represents. For more information about the interface a user defined token type has to expose please look at the Token Class reference. The library provides a default token type based on the Lexertl library which should be sufficient in most cases: the `lex::lexertl::token<>` type. This section focusses on the description of general features a token class may implement and how this integrates with the other parts of the *Spirit.Lex* library.

The Anatomy of a Token

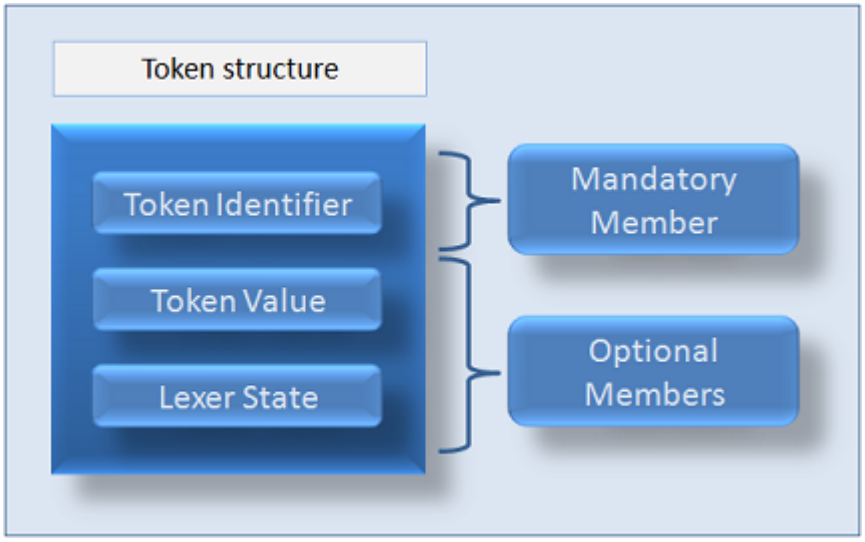
It is very important to understand the difference between a token definition (represented by the `lex::token_def<>` template) and a token itself (for instance represented by the `lex::lexertl::token<>` template).

The token definition is used to describe the main features of a particular token type, especially:

- to simplify the definition of a token type using a regular expression pattern applied while matching this token type,
- to associate a token type with a particular lexer state,
- to optionally assign a token id to a token type,
- to optionally associate some code to execute whenever an instance of this token type has been matched,
- and to optionally specify the attribute type of the token value.

The token itself is a data structure returned by the lexer iterators. Dereferencing a lexer iterator returns a reference to the last matched token instance. It encapsulates the part of the underlying input sequence matched by the regular expression used during the definiton of this token type. Incrementing the lexer iterator invokes the lexical analyzer to match the next token by advancing the underlying input stream. The token data structure contains at least the token id of the matched token type, allowing to identify the matched character sequence. Optionally, the token instance may contain a token value and/or the lexer state this token instance was matched in. The following figure shows the schematic structure of a token.

Figure 8. The structure of a token



The token value and the lexer state the token has been recognized in may be omitted for optimization reasons, thus avoiding the need for the token to carry more data than actually required. This configuration can be achieved by supplying appropriate template parameters for the `lex::lexertl::token<>` template while defining the token type.

The lexer iterator returns the same token type for each of the different matched token definitions. To accomodate for the possible different token *value* types exposed by the various token types (token definitions), the general type of the token value is a Boost.Variant. At a minimum (for the default configuration) this token value variant will be configured to always hold a `boost::iterator_range` containing the pair of iterators pointing to the matched input sequence for this token instance.

Note

If the lexical analyzer is used in conjunction with a *Spirit.Qi* parser, the stored `boost::iterator_range` token value will be converted to the requested token type (parser attribute) exactly once. This happens at the time of the first access to the token value requiring the corresponding type conversion. The converted token value will be stored in the Boost.Variant replacing the initially stored iterator range. This avoids having to convert the input sequence to the token value more than once, thus optimizing the integration of the lexer with *Spirit.Qi*, even during parser backtracking.

Here is the template prototype of the `lex::lexertl::token<>` template:

```
template <
    typename Iterator = char const*,
    typename AttributeTypes = mpl::vector0<>,
    typename HasState = mpl::true_
>
struct lexertl_token;
```

where:

Iterator — This is the type of the iterator used to access the underlying input stream. It defaults to a plain `char const*`.

AttributeTypes — This is either a mpl sequence containing all attribute types used for the token definitions or the type `omit`. If the mpl sequence is empty (which is the default), all token instances will store a `boost::iterator_range<Iterator>` pointing to the start and the end of the matched section in the input stream. If the type is `omit`, the generated tokens will contain no token value (attribute) at all.

HasState — This is either `mpl::true_` or `mpl::false_`, allowing control as to whether the generated token instances will contain the lexer state they were generated in. The default is mpl::true_, so all token instances will contain the lexer state.

Normally, during construction, a token instance always holds the `boost::iterator_range` as its token value, unless it has been defined using the `omit` token value type. This iterator range then is converted in place to the requested token value type (attribute) when it is requested for the first time.

The Physiognomy of a Token Definition

The token definitions (represented by the `lex::token_def<>` template) are normally used as part of the definition of the lexical analyzer. At the same time a token definition instance may be used as a parser component in *Spirit.Qi*.

The template prototype of this class is shown here:

```
template<
    typename Attribute = unused_type,
    typename Char = char
>
class token_def;
```

where:

Attribute — This is the type of the token value (attribute) supported by token instances representing this token type. This attribute type is exposed to the *Spirit.Qi* library, whenever this token definition is used as a parser component. The default attribute type is `unused_type`, which means the token instance holds a `boost::iterator_range` pointing to the start and the end of the matched section in the input stream. If the attribute is `omit` the token instance will expose no token type at all. Any other type will be used directly as the token value type.

Char — This is the value type of the iterator for the underlying input sequence. It defaults to `char`.

The semantics of the template parameters for the token type and the token definition type are very similar and interdependent. As a rule of thumb you can think of the token definition type as the means of specifying everything related to a single specific token type (such as `identifier` or `integer`). On the other hand the token type is used to define the general properties of all token instances generated by the *Spirit.Lex* library.

Important

If you don't list any token value types in the token type definition declaration (resulting in the usage of the default `boost::iterator_range` token type) everything will compile and work just fine, just a bit less efficient. This is because the token value will be converted from the matched input sequence every time it is requested.

But as soon as you specify at least one token value type while defining the token type you'll have to list all value types used for `lex::token_def<>` declarations in the token definition class, otherwise compilation errors will occur.

Examples of using `lex::lexertl::token<>`

Let's start with some examples. We refer to one of the *Spirit.Lex* examples (for the full source code of this example please see example4.cpp).

The first code snippet shows an excerpt of the token definition class, the definition of a couple of token types. Some of the token types do not expose a special token value (`if_`, `else_`, and `while_`). Their token value will always hold the iterator range of the matched input sequence. The token definitions for the `identifier` and the integer `constant` are specialized to expose an explicit token type each: `std::string` and `unsigned int`.

```
// these tokens expose the iterator_range of the matched input sequence
lex::token_def<> if_, else_, while_;

// The following two tokens have an associated attribute type, 'identifier'
// carries a string (the identifier name) and 'constant' carries the
// matched integer value.
//
// Note: any token attribute type explicitly specified in a token_def<>
//       declaration needs to be listed during token type definition as
//       well (see the typedef for the token_type below).
//
// The conversion of the matched input to an instance of this type occurs
// once (on first access), which makes token attributes as efficient as
// possible. Moreover, token instances are constructed once by the lexer
// library. From this point on tokens are passed by reference only,
// avoiding them being copied around.
lex::token_def<std::string> identifier;
lex::token_def<unsigned int> constant;
```

As the parsers generated by *Spirit.Qi* are fully attributed, any *Spirit.Qi* parser component needs to expose a certain type as its parser attribute. Naturally, the `lex::token_def<>` exposes the token value type as its parser attribute, enabling a smooth integration with *Spirit.Qi*.

The next code snippet demonstrates how the required token value types are specified while defining the token type to use. All of the token value types used for at least one of the token definitions have to be re-iterated for the token definition as well.

```
// This is the lexer token type to use. The second template parameter lists
// all attribute types used for token_def's during token definition (see
// calculator_tokens<> above). Here we use the predefined lexertl token
// type, but any compatible token type may be used instead.
//
// If you don't list any token attribute types in the following declaration
// (or just use the default token type: lexertl_token<base_iterator_type>)
// it will compile and work just fine, just a bit less efficient. This is
// because the token attribute will be generated from the matched input
// sequence every time it is requested. But as soon as you specify at
// least one token attribute type you'll have to list all attribute types
// used for token_def<> declarations in the token definition class above,
// otherwise compilation errors will occur.
typedef lex::lexertl::token<
    base_iterator_type, boost::mpl::vector<unsigned int, std::string>
> token_type;
```

To avoid the token to have a token value at all, the special tag `omit` can be used: `token_def<omit>` and `lexertl_token<base_iterator_type, omit>`.

Tokenizing Input Data

The tokenize function

The `tokenize()` function is a helper function simplifying the usage of a lexer in a standalone fashion. For instance, you may have a standalone lexer where all that functional requirements are implemented inside lexer semantic actions. A good example for this is the word_count_lexer described in more detail in the section Lex Quickstart 2 - A better word counter using *Spirit.Lex*.

```
template <typename Lexer>
struct word_count_tokens : lex::lexer<Lexer>
{
    word_count_tokens()
      : c(0), w(0), l(0)
      , word("[^ \t\n]+")     // define tokens
      , eol("\n")
      , any(".")
    {
        using boost::spirit::lex::_start;
        using boost::spirit::lex::_end;
        using boost::phoenix::ref;

        // associate tokens with the lexer
        this->self
            =   word  [++ref(w), ref(c) += distance(_start, _end)]
            |   eol   [++ref(c), ++ref(l)]
            |   any   [++ref(c)]
            ;
    }

    std::size_t c, w, l;
    lex::token_def<> word, eol, any;
};
```

The construct used to tokenize the given input, while discarding all generated tokens is a common application of the lexer. For this reason *Spirit.Lex* exposes an API function `tokenize()` minimizing the code required:

```
// Read input from the given file
std::string str (read_from_file(1 == argc ? "word_count.input" : argv[1]));

word_count_tokens<lexer_type> word_count_lexer;
std::string::iterator first = str.begin();

// Tokenize all the input, while discarding all generated tokens
bool r = tokenize(first, str.end(), word_count_lexer);
```

This code is completely equivalent to the more verbose version as shown in the section Lex Quickstart 2 - A better word counter using *Spirit.Lex*. The function `tokenize()` will return either if the end of the input has been reached (in this case the return value will be `true`), or if the lexer couldn't match any of the token definitions in the input (in this case the return value will be `false` and the iterator `first` will point to the first not matched character in the input sequence).

The prototype of this function is:

```
template <typename Iterator, typename Lexer>
bool tokenize(Iterator& first, Iterator last, Lexer const& lex
  , typename Lexer::char_type const* initial_state = 0);
```

where:

Iterator& first	The beginning of the input sequence to tokenize. The value of this iterator will be updated by the lexer, pointing to the first not matched character of the input after the function returns.
Iterator last	The end of the input sequence to tokenize.
Lexer const& lex	The lexer instance to use for tokenization.
Lexer::char_type const* initial_state	This optional parameter can be used to specify the initial lexer state for tokenization.

A second overload of the `tokenize()` function allows specifying of any arbitrary function or function object to be called for each of the generated tokens. For some applications this is very useful, as it might avoid having lexer semantic actions. For an example of how to use this function, please have a look at word_count_functor.cpp:

The main function simply loads the given file into memory (as a `std::string`), instantiates an instance of the token definition template using the correct iterator type (`word_count_tokens<char const*>`), and finally calls `lex::tokenize`, passing an instance of the counter function object. The return value of `lex::tokenize()` will be `true` if the whole input sequence has been successfully tokenized, and `false` otherwise.

```
int main(int argc, char* argv[])
{
    // these variables are used to count characters, words and lines
    std::size_t c = 0, w = 0, l = 0;

    // read input from the given file
    std::string str (read_from_file(1 == argc ? "word_count.input" : argv[1]));

    // create the token definition instance needed to invoke the lexical analyzer
    word_count_tokens<lex::lexertl::lexer<> > word_count_functor;

    // tokenize the given string, the bound functor gets invoked for each of
    // the matched tokens
    char const* first = str.c_str();
    char const* last = &first[str.size()];
    bool r = lex::tokenize(first, last, word_count_functor,
        boost::bind(counter(), _1, boost::ref(c), boost::ref(w), boost::ref(l)));

    // print results
    if (r) {
        std::cout << "lines: " << l << ", words: " << w
                  << ", characters: " << c << "\n";
    }
    else {
        std::string rest(first, last);
        std::cout << "Lexical analysis failed\n" << "stopped at: \""
                  << rest << "\"\n";
    }
    return 0;
}
```

Here is the prototype of this `tokenize()` function overload:

```
template <typename Iterator, typename Lexer, typename F>
bool tokenize(Iterator& first, Iterator last, Lexer const& lex, F f
  , typename Lexer::char_type const* initial_state = 0);
```

where:

Iterator& first	The beginning of the input sequence to tokenize. The value of this iterator will be updated by the lexer, pointing to the first not matched character of the input after the function returns.
Iterator last	The end of the input sequence to tokenize.
Lexer const& lex	The lexer instance to use for tokenization.
F f	A function or function object to be called for each matched token. This function is expected to have the prototype: `bool f(Lexer::token_type);`. The `tokenize()` function will return immediately if `F` returns `false.
Lexer::char_type const* initial_state	This optional parameter can be used to specify the initial lexer state for tokenization.

The generate_static function

Lexer Semantic Actions

The main task of a lexer normally is to recognize tokens in the input. Traditionally this has been complemented with the possibility to execute arbitrary code whenever a certain token has been detected. *Spirit.Lex* has been designed to support this mode of operation as well. We borrow from the concept of semantic actions for parsers (*Spirit.Qi*) and generators (*Spirit.Karma*). Lexer semantic actions may be attached to any token definition. These are C++ functions or function objects that are called whenever a token definition

successfully recognizes a portion of the input. Say you have a token definition `D`, and a C++ function `f`, you can make the lexer call `f` whenever it matches an input by attaching `f`:

```
D[f]
```

The expression above links `f` to the token definition, `D`. The required prototype of `f` is:

```
void f (Iterator& start, Iterator& end, pass_flag& matched, Idtype& id, Context& ctx);
```

where:

`Iterator& start`	This is the iterator pointing to the begin of the matched range in the underlying input sequence. The type of the iterator is the same as specified while defining the type of the `lexertl::actor_lexer<...>` (its first template parameter). The semantic action is allowed to change the value of this iterator influencing, the matched input sequence.
`Iterator& end`	This is the iterator pointing to the end of the matched range in the underlying input sequence. The type of the iterator is the same as specified while defining the type of the `lexertl::actor_lexer<...>` (its first template parameter). The semantic action is allowed to change the value of this iterator influencing, the matched input sequence.
`pass_flag& matched`	This value is pre/initialized to `pass_normal`. If the semantic action sets it to `pass_fail` this behaves as if the token has not been matched in the first place. If the semantic action sets this to `pass_ignore` the lexer ignores the current token and tries to match a next token from the input.
`Idtype& id`	This is the token id of the type Idtype (most of the time this will be a `std::size_t`) for the matched token. The semantic action is allowed to change the value of this token id, influencing the if of the created token.
`Context& ctx`	This is a reference to a lexer specific, unspecified type, providing the context for the current lexer state. It can be used to access different internal data items and is needed for lexer state control from inside a semantic action.

When using a C++ function as the semantic action the following prototypes are allowed as well:

```
void f (Iterator& start, Iterator& end, pass_flag& matched, Idtype& id);
void f (Iterator& start, Iterator& end, pass_flag& matched);
void f (Iterator& start, Iterator& end);
void f ();
```

Important

In order to use lexer semantic actions you need to use type `lexertl::actor_lexer<>` as your lexer class (instead of the type `lexertl::lexer<>` as described in earlier examples).

The context of a lexer semantic action

The last parameter passed to any lexer semantic action is a reference to an unspecified type (see the `Context` type in the table above). This type is unspecified because it depends on the token type returned by the lexer. It is implemented in the internals of the iterator type exposed by the lexer. Nevertheless, any context type is expected to expose a couple of functions allowing to influence the behavior of the lexer. The following table gives an overview and a short description of the available functionality.

Table 8. Functions exposed by any context passed to a lexer semantic action

Name	Description
`Iterator const& get_eoi() const`	The function `get_eoi()` may be used by to access the end iterator of the input stream the lexer has been initialized with
`void more()`	The function `more()` tells the lexer that the next time it matches a rule, the corresponding token should be appended onto the current token value rather than replacing it.
`Iterator const& less(Iterator const& it, int n)`	The function `less()` returns an iterator positioned to the nth input character beyond the current token start iterator (i.e. by passing the return value to the parameter `end` it is possible to return all but the first n characters of the current token back to the input stream.
`bool lookahead(std::size_t id)`	The function `lookahead()` can be used to implement lookahead for lexer engines not supporting constructs like flex' `a/b` (match `a`, but only when followed by `b`). It invokes the lexer on the input following the current token without actually moving forward in the input stream. The function returns whether the lexer was able to match a token with the given token-id `id`.
`std::size_t get_state() const` and `void set_state(std::size_t state)`	The functions `get_state()` and `set_state()` may be used to introspect and change the current lexer state.
`token_value_type get_value() const` and `void set_value(Value const&)`	The functions `get_value()` and `set_value()` may be used to introspect and change the current token value.

Lexer Semantic Actions Using Phoenix

Even if it is possible to write your own function object implementations (i.e. using Boost.Lambda or Boost.Bind), the preferred way of defining lexer semantic actions is to use Boost.Phoenix. In this case you can access the parameters described above by using the predefined Spirit placeholders:

Table 9. Predefined Phoenix placeholders for lexer semantic actions

Placeholder	Description
`_start`	Refers to the iterator pointing to the beginning of the matched input sequence. Any modifications to this iterator value will be reflected in the generated token.
`_end`	Refers to the iterator pointing past the end of the matched input sequence. Any modifications to this iterator value will be reflected in the generated token.
`_pass`	References the value signaling the outcome of the semantic action. This is pre-initialized to `lex::pass_flags::pass_normal`. If this is set to `lex::pass_flags::pass_fail`, the lexer will behave as if no token has been matched, if is set to `lex::pass_flags::pass_ignore`, the lexer will ignore the current match and proceed trying to match tokens from the input.
`_tokenid`	Refers to the token id of the token to be generated. Any modifications to this value will be reflected in the generated token.
`_val`	Refers to the value the next token will be initialized from. Any modifications to this value will be reflected in the generated token.
`_state`	Refers to the lexer state the input has been match in. Any modifications to this value will be reflected in the lexer itself (the next match will start in the new state). The currently generated token is not affected by changes to this variable.
`_eoi`	References the end iterator of the overall lexer input. This value cannot be changed.

The context object passed as the last parameter to any lexer semantic action is not directly accessible while using Boost.Phoenix expressions. We rather provide predefine Phoenix functions allowing to invoke the different support functions as mentioned above. The following table lists the available support functions and describes their functionality:

Table 10. Support functions usable from Phoenix expressions inside lexer semantic actions

Plain function	Phoenix function	Description
`ctx.more()`	`more()`	The function `more()` tells the lexer that the next time it matches a rule, the corresponding token should be appended onto the current token value rather than replacing it.
`ctx.less()`	`less(n)`	The function `less()` takes a single integer parameter `n` and returns an iterator positioned to the nth input character beyond the current token start iterator (i.e. by assigning the return value to the placeholder `_end` it is possible to return all but the first `n` characters of the current token back to the input stream.
`ctx.lookahead()`	`lookahead(std::size_t)` or `lookahead(token_def)`	The function `lookahead()` takes a single parameter specifying the token to match in the input. The function can be used for instance to implement lookahead for lexer engines not supporting constructs like flex' `a/b` (match `a`, but only when followed by `b`). It invokes the lexer on the input following the current token without actually moving forward in the input stream. The function returns whether the lexer was able to match the specified token.

The *Static* Lexer Model

The documentation of *Spirit.Lex* so far mostly was about describing the features of the *dynamic* model, where the tables needed for lexical analysis are generated from the regular expressions at runtime. The big advantage of the dynamic model is its flexibility, and its integration with the Spirit library and the C++ host language. Its big disadvantage is the need to spend additional runtime to generate the tables, which especially might be a limitation for larger lexical analyzers. The *static* model strives to build upon the smooth integration with Spirit and C++, and reuses large parts of the *Spirit.Lex* library as described so far, while overcoming the additional runtime requirements by using pre-generated tables and tokenizer routines. To make the code generation as simple as possible, the static model reuses the token definition types developed for the *dynamic* model without any changes. As will be shown in this section, building a code generator based on an existing token definition type is a matter of writing 3 lines of code.

Assuming you already built a dynamic lexer for your problem, there are two more steps needed to create a static lexical analyzer using *Spirit.Lex*:

1. generating the C++ code for the static analyzer (including the tokenization function and corresponding tables), and

2. modifying the dynamic lexical anlyzer to use the generated code.

Both steps are described in more detail in the two sections below (for the full source code used in this example see the code here: the common token definition, the code generator, the generated code, and the static lexical analyzer).

But first we provide the code snippets needed to further understand the descriptions. Both, the definition of the used token identifier and the of the token definition class in this example are put into a separate header file to make these available to the code generator and the static lexical analyzer.

```
enum tokenids
{
    IDANY = boost::spirit::lex::min_token_id + 1,
};
```

The important point here is, that the token definition class is not different from a similar class to be used for a dynamic lexical analyzer. The library has been designed in a way, that all components (dynamic lexical analyzer, code generator, and static lexical analyzer) can reuse the very same token definition syntax.

```
// This token definition class can be used without any change for all three
// possible use cases: a dynamic lexical analyzer, a code generator, and a
// static lexical analyzer.
template <typename BaseLexer>
struct word_count_tokens : boost::spirit::lex::lexer<BaseLexer>
{
    word_count_tokens()
      : word_count_tokens::base_type(
          boost::spirit::lex::match_flags::match_not_dot_newline)
    {
        // define tokens and associate them with the lexer
        word = "[^ \t\n]+";
        this->self = word | '\n' | boost::spirit::lex::token_def<>(".", IDANY);
    }

    boost::spirit::lex::token_def<std::string> word;
};
```

The only thing changing between the three different use cases is the template parameter used to instantiate a concrete token definition. Fot the dynamic model and the code generator you probably will use the `lex::lexertl::lexer<>` template, where for the static model you will use the `lex::lexertl::static_lexer<>` type as the template parameter.

This example not only shows how to build a static lexer, but it additionally demonstrates how such a lexer can be used for parsing in conjunction with a *Spirit.Qi* grammar. For completeness, we provide the simple grammar used in this example. As you can see, this grammar does not have any dependencies on the static lexical analyzer, and for this reason it is not different from a grammar used either without a lexer or using a dynamic lexical analyzer as described before.

```
//  This is an ordinary grammar definition following the rules defined by
//  Spirit.Qi. There is nothing specific about it, except it gets the token
//  definition class instance passed to the constructor to allow accessing the
//  embedded token_def<> instances.
template <typename Iterator>
struct word_count_grammar : qi::grammar<Iterator>
{
    template <typename TokenDef>
    word_count_grammar(TokenDef const& tok)
      : word_count_grammar::base_type(start)
      , c(0), w(0), l(0)
    {
        using boost::phoenix::ref;
        using boost::phoenix::size;

        //  associate the defined tokens with the lexer, at the same time
        //  defining the actions to be executed
        start =  *(   tok.word          [ ++ref(w), ref(c) += size(_1) ]
                  |   lit('\n')         [ ++ref(l), ++ref(c) ]
                  |   qi::token(IDANY)  [ ++ref(c) ]
                  )
                ;
    }

    std::size_t c, w, l;      // counter for characters, words, and lines
    qi::rule<Iterator> start;
};
```

Generating the Static Analyzer

The first additional step to perform in order to create a static lexical analyzer is to create a small standalone program for creating the lexer tables and the corresponding tokenization function. For this purpose the *Spirit.Lex* library exposes a special API - the function `generate_static()` . It implements the whole code generator, no further code is needed. All what it takes to invoke this function is to supply a token definition instance, an output stream to use to generate the code to, and an optional string to be used as a suffix for the name of the generated function. All in all just a couple lines of code.

```
int main(int argc, char* argv[])
{
    // create the lexer object instance needed to invoke the generator
    word_count_tokens<lex::lexertl::lexer<> > word_count; // the token definition

    // open the output file, where the generated tokenizer function will be
    // written to
    std::ofstream out(argc < 2 ? "word_count_static.hpp" : argv[1]);

    // invoke the generator, passing the token definition, the output stream
    // and the name suffix of the tables and functions to be generated
    //
    // The suffix "wc" used below results in a type lexertl::static_::lexer_wc
    // to be generated, which needs to be passed as a template parameter to the
    // lexertl::static_lexer template (see word_count_static.cpp).
    return lex::lexertl::generate_static(word_count, out, "wc") ? 0 : -1;
}
```

The shown code generator will generate output, which should be stored in a file for later inclusion into the static lexical analzyer as shown in the next topic (the full generated code can be viewed here).

Note

The generated code will have compiled in the version number of the current *Spirit.Lex* library. This version number is used at compilation time of your static lexer object to ensure this is compiled using exactly the same version of the *Spirit.Lex* library as the lexer tables have been generated with. If the versions do not match you will see an compilation error mentioning an `incompatible_static_lexer_version`.

Modifying the Dynamic Analyzer

The second required step to convert an existing dynamic lexer into a static one is to change your main program at two places. First, you need to change the type of the used lexer (that is the template parameter used while instantiating your token definition class). While in the dynamic model we have been using the `lex::lexertl::lexer<>` template, we now need to change that to the `lex::lexertl::static_lexer<>` type. The second change is tightly related to the first one and involves correcting the corresponding `#include` statement to:

```
#include <boost/spirit/include/lex_static_lexertl.hpp>
```

Otherwise the main program is not different from an equivalent program using the dynamic model. This feature makes it easy to develop the lexer in dynamic mode and to switch to the static mode after the code has been stabilized. The simple generator application shown above enables the integration of the code generator into any existing build process. The following code snippet provides the overall main function, highlighting the code to be changed.

```
int main(int argc, char* argv[])
{
    // Define the token type to be used: 'std::string' is available as the type
    // of the token value.
    typedef lex::lexertl::token<
        char const*, boost::mpl::vector<std::string>
    > token_type;

    // Define the lexer type to be used as the base class for our token
    // definition.
    //
    // This is the only place where the code is different from an equivalent
    // dynamic lexical analyzer. We use the `lexertl::static_lexer<>` instead of
    // the `lexertl::lexer<>` as the base class for our token defintion type.
    //
    // As we specified the suffix "wc" while generating the static tables we
    // need to pass the type lexertl::static_::lexer_wc as the second template
    // parameter below (see word_count_generate.cpp).
    typedef lex::lexertl::static_lexer<
        token_type, lex::lexertl::static_::lexer_wc
    > lexer_type;

    // Define the iterator type exposed by the lexer.
    typedef word_count_tokens<lexer_type>::iterator_type iterator_type;

    // Now we use the types defined above to create the lexer and grammar
    // object instances needed to invoke the parsing process.
    word_count_tokens<lexer_type> word_count;           // Our lexer
    word_count_grammar<iterator_type> g (word_count);   // Our parser

    // Read in the file into memory.
    std::string str (read_from_file(1 == argc ? "word_count.input" : argv[1]));
    char const* first = str.c_str();
    char const* last = &first[str.size()];

    // Parsing is done based on the the token stream, not the character stream.
    bool r = lex::tokenize_and_parse(first, last, word_count, g);

    if (r) {    // success
        std::cout << "lines: " << g.l << ", words: " << g.w
                  << ", characters: " << g.c << "\n";
    }
    else {
        std::string rest(first, last);
        std::cerr << "Parsing failed\n" << "stopped at: \""
                  << rest << "\"\n";
    }
    return 0;
}
```

Important

The generated code for the static lexer contains the token ids as they have been assigned, either explicitly by the programmer or implicitely during lexer construction. It is your responsibility to make sure that all instances of a particular static lexer type use exactly the same token ids. The constructor of the lexer object has a second (default) parameter allowing it to designate a starting token id to be used while assigning the ids to the token definitions. The requirement above is fullfilled by default as long as no `first_id` is specified during construction of the static lexer instances.

Quick Reference

This quick reference section is provided for convenience. You can use this section as a sort of a "cheat-sheet" on the most commonly used Lex components. It is not intended to be complete, but should give you an easy way to recall a particular component without having to dig through pages and pages of reference doumentation.

Common Notation

Notation

`L`	Lexer type
`l, a, b, c, d`	Lexer objects
`Iterator`	The type of an iterator referring to the underlying input sequence
`IdType`	The token id type
`Context`	The lexer components `Context` type
`ch`	Character-class specific character (See Character Class Types)
`Ch`	Character-class specific character type (See Character Class Types)
`str`	Character-class specific string (See Character Class Types)
`Str`	Character-class specific string type (See Character Class Types)
`Attrib`	An attribute type
`fa`	A semantic action function with a signature: `void f(Iterator&, Iterator&, pass_flag&, Idtype&, Context&)`.

Primitive Lexer Components

Expression	Attribute	Description
`ch`	n/a	Matches `ch`
`char_(ch)`	n/a	Matches `ch`
`str`	n/a	Matches regular expression `str`
`string(str)`	n/a	Matches regular expression `str`
`token_def<Attrib>`	`Attrib`	Matches the immediate argument
`a | b`	n/a	Matches any of the expressions `a` or `b`
`l[fa]`	Attribute of `l`	Call semantic action `fa` (after matching `l`).

Note

The column *Attribute* in the table above lists the parser attribute exposed by the lexer component if it is used as a parser (see Attribute). A 'n/a' in this columns means the lexer component is not usable as a parser.

Semantic Actions

Has the form:

```
l[f]
```

where `f` is a function with the signatures:

```
void f();
void f(Iterator&, Iterator&);
void f(Iterator&, Iterator&, pass_flag&);
void f(Iterator&, Iterator&, pass_flag&, Idtype&);
void f(Iterator&, Iterator&, pass_flag&, Idtype&, Context&);
```

You can use Boost.Bind to bind member functions. For function objects, the allowed signatures are:

```
void operator()(unused_type, unused_type, unused_type, unused_type, unused_type) const;
void operator()(Iterator&, Iterator&, unused_type, unused_type, unused_type) const;
void operator()(Iterator&, Iterator&, pass_flag&, unused_type, unused_type) const;
void operator()(Iterator&, Iterator&, pass_flag&, Idtype&, unused_type) const;
void operator()(Iterator&, Iterator&, pass_flag&, Idtype&, Context&) const;
```

The `unused_type` is used in the signatures above to signify 'don't care'.

For more information see Lexer Semantic Actions.

Phoenix

Boost.Phoenix makes it easier to attach semantic actions. You just inline your lambda expressions:

```
l[phoenix-lambda-expression]
```

Spirit.Lex provides some Boost.Phoenix placeholders to access important information from the `Context` that are otherwise difficult to extract.

Spirit.Lex specific Phoenix placeholders

`_start, _end`	Iterators pointing to the begin and the end of the matched input sequence.
`_pass`	Assign `false` to `_pass` to force the current match to fail.
`_tokenid`	The token id of the matched token.
`_val`	The token value of the matched token.
`_state`	The lexer state the token has been matched in.
`_eoi`	Iterator referring to the current end of the input sequence.

Tip

All of the placeholders in the list above (except `_eoi`) can be changed from the inside of the semantic action allowing to modify the lexer behavior. They are defined in the namespace `boost::spirit::lex`.

For more information see Lexer Semantic Actions.

Supported Regular Expressions

Table 11. Regular expressions support

Expression	Meaning
`x`	Match any character `x`
`.`	Match any except newline (or optionally **any** character)
`"..."`	All characters taken as literals between double quotes, except escape sequences
`[xyz]`	A character class; in this case matches `x`, `y` or `z`
`[abj-oZ]`	A character class with a range in it; matches `a`, `b` any letter from `j` through `o` or a `Z`
`[^A-Z]`	A negated character class i.e. any character but those in the class. In this case, any character except an uppercase letter
`r*`	Zero or more r's (greedy), where r is any regular expression
`r*?`	Zero or more r's (abstemious), where r is any regular expression
`r+`	One or more r's (greedy)
`r+?`	One or more r's (abstemious)
`r?`	Zero or one r's (greedy), i.e. optional
`r??`	Zero or one r's (abstemious), i.e. optional
`r{2,5}`	Anywhere between two and five r's (greedy)
`r{2,5}?`	Anywhere between two and five r's (abstemious)
`r{2,}`	Two or more r's (greedy)
`r{2,}?`	Two or more r's (abstemious)
`r{4}`	Exactly four r's
`{NAME}`	The macro `NAME` (see below)
`"[xyz]\"foo"`	The literal string `[xyz]\"foo`
`\X`	If X is `a`, `b`, `e`, `n`, `r`, `f`, `t`, `v` then the ANSI-C interpretation of `\x`. Otherwise a literal `X` (used to escape operators such as `*`)
`\0`	A NUL character (ASCII code 0)
`\123`	The character with octal value 123
`\x2a`	The character with hexadecimal value 2a
`\cX`	A named control character `X`.
`\a`	A shortcut for Alert (bell).

Expression	Meaning
`\b`	A shortcut for Backspace
`\e`	A shortcut for ESC (escape character `0x1b`)
`\n`	A shortcut for newline
`\r`	A shortcut for carriage return
`\f`	A shortcut for form feed `0x0c`
`\t`	A shortcut for horizontal tab `0x09`
`\v`	A shortcut for vertical tab `0x0b`
`\d`	A shortcut for `[0-9]`
`\D`	A shortcut for `[^0-9]`
`\s`	A shortcut for `[\x20\t\n\r\f\v]`
`\S`	A shortcut for `[^\x20\t\n\r\f\v]`
`\w`	A shortcut for `[a-zA-Z0-9_]`
`\W`	A shortcut for `[^a-zA-Z0-9_]`
`(r)`	Match an `r`; parenthesis are used to override precedence (see below)
`(?r-s:pattern)`	apply option 'r' and omit option 's' while interpreting pattern. Options may be zero or more of the characters 'i' or 's'. 'i' means case-insensitive. '-i' means case-sensitive. 's' alters the meaning of the '.' syntax to match any single character whatsoever. '-s' alters the meaning of '.' to match any character except '`\n`'.
`rs`	The regular expression `r` followed by the regular expression `s` (a sequence)
`r|s`	Either an `r` or and `s`
`^r`	An `r` but only at the beginning of a line (i.e. when just starting to scan, or right after a newline has been scanned)
`r$`	An `r` but only at the end of a line (i.e. just before a newline)

Note

POSIX character classes are not currently supported, due to performance issues when creating them in wide character mode.

Regular Expression Precedence

- `rs` has highest precedence
- `r*` has next highest (`+`, `?`, `{n,m}` have the same precedence as `*`)

- `r|s` has the lowest precedence

Macros

Regular expressions can be given a name and referred to in rules using the syntax `{NAME}` where `NAME` is the name you have given to the macro. A macro name can be at most 30 characters long and must start with a _ or a letter. Subsequent characters can be _, `-`, a letter or a decimal digit.

Reference

Lexer Concepts

Spirit.Lex components fall into a couple of generalized concepts. The *Lexer* is the most fundamental concept. All *Spirit.Lex* components are models of the *Lexer* concept. *PrimitiveLexer*, *UnaryLexer*, and *NaryLexer* are all refinements of the *Lexer* concept.

The following sections provide details on these concepts.

Lexer

Description

The *Lexer* is the most fundamental concept. A Lexer has a member function, `collect`, that accepts a token definition container `Def`, and a the name of the lexer state the token definitions of the lexer component need to be added to (a string). It doesn't return anything (return type is `void`). Each Lexer can represent a specific pattern or algorithm, or it can be a more complex lexer component formed as a composition of other Lexer's. Additionally, a Lexer exposes a member `add_actions`, that accepts the token definition container `Def`, while returning nothing (again, the returned type is `void`).

Notation

`l` A `Lexer`.

`L` A `Lexer` type.

`Def` A token definition conatiner type.

`State` A type used to represent lexer state names.

Valid Expressions

In the expressions below, the behavior of the lexer component, `l`, is left unspecified in the base `Lexer` concept. These are specified in subsequent, more refined concepts and by the actual models thereof.

For any Lexer the following expressions must be valid:

Expression	Semantics	Return type
`l.collect(def, state)`	Add all token definitions provided by this Lexer instance to the lexer state `state` of the token definition container `def`.	`void`
`l.add_actions(def)`	Add all semantic actions provided by this Lexer instance to the token definition container `def`.	`void`

Type Expressions

Expression	Description
`traits::is_lexer<L>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `L` is a Lexer, `mpl::false_` otherwise (See MPL Boolean Constant).

Postcondition

Upon return from `l.collect` the following post conditions should hold:

- On return, `def` holds all token definitions defined in the Lexer, `l`. This includes all Lexer's contained inside `l`.

Upon return from `l.add_actions` the following post conditions should hold:

- On return, `def` holds all semantic actions correctly asociated with the corresponding token definitions as defined in the Lexer, `l`. This includes all semantic actiosn defined by the Lexer's contained inside `l`.

Models

All lexer components in *Spirit.Lex* are models of the *Lexer* concept.

PrimitiveLexer

Description

PrimitiveLexer is the most basic building block that the client uses to build more complex lexer components.

Refinement of

`Lexer`

Type Expressions

Expression	Description
`traits::is_primitive_lexer<L>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `L`, is a PrimitiveLexer, `mpl::false_` otherwise (See MPL Boolean Constant).

Models

The following lexer components conform to this model:

- character literals (i.e. `'x'`), `char_`,
- string literals (`"abc"`), `std::basic_string<>`, `string`

FIXME Add more links to *PrimitiveLexer* models here.

UnaryLexer

Description

UnaryLexer is a composite lexer component that has a single subject. The UnaryLexer may change the behavior of its subject following the Delegate Design Pattern.

Refinement of

`Lexer`

Notation

`l` A UnaryLexer.

`L` A UnaryLexer type.

Valid Expressions

In addition to the requirements defined in `Lexer`, for any UnaryLexer the following must be met:

Expression	Semantics	Return type
`l.subject`	Subject lexer component.	`Lexer`

Type Expressions

Expression	Description
`L::subject_type`	The subject lexer component type.
`traits::is_unary_lexer<L>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `L` is a UnaryLexer, `mpl::false_` otherwise (See MPL Boolean Constant).

Invariants

For any UnaryLexer, `L`, the following invariant always holds:

- `traits::is_lexer<L::subject_type>::type` evaluates to `mpl::true_`

Models

The following lexer components conform to this model:

- action lexer component (allowing to attach semantic actions)

FIXME Add more links to models of UnaryLexer concept

NaryLexer

Description

NaryLexer is a composite lexer component that has one or more subjects. The NaryLexer allows its subjects to be treated in the same way as a single instance of a `Lexer` following the Composite Design Pattern.

Refinement of

`Lexer`

Notation

`l` A NaryLexer.

`L` A NaryLexer type.

Valid Expressions

In addition to the requirements defined in `Lexer`, for any NaryLexer the following must be met:

Expression	Semantics	Return type
`l.elements`	The tuple of elements.	A Boost.Fusion Sequence of `Lexer` types.

Type Expressions

Expression	Description
`l.elements_type`	Elements tuple type.
`traits::is_nary_lexer<L>::type`	Metafunction that evaluates to `mpl::true_` if a certain type, `L` is a NaryLexer, `mpl::false_` otherwise (See MPL Boolean Constant).

Invariants

For each element, `E`, in any NaryLexer, `L`, the following invariant always holds:

- `traits::is_lexer<E>::type` evaluates to `mpl::true_`

Models

The following lexer components conform to this model:

- lexer sequence component

FIXME Add more links to models of NaryLexer concept

Basics

Examples

All sections in the reference present some real world examples. The examples use a common test harness to keep the example code as minimal and direct to the point as possible. The test harness is presented below.

Some includes:

```
#include <boost/spirit/include/lex.hpp>
#include <boost/spirit/include/phoenix_core.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <iostream>
#include <string>
```

Our test functions:

This one tests token definitions.

Models

Predefined models include:

- any literal string, e.g. "Hello, World",
- a pointer/reference to a null-terminated array of characters

- a `std::basic_string<Char>`

The namespace `boost::spirit::traits` is open for users to provide their own specializations.

Lexer API

Description

The library provides a couple of free functions to make using the lexer a snap. These functions have three forms. The first form, `tokenize`, simplifies the usage of a standalone lexer (without parsing). The second form, `tokenize_and_parse`, combines a lexer step with parsing on the token level (without a skipper). The third, `tokenize_and_phrase_parse`, works on the token level as well, but additionally employs a skip parser. The latter two versions can take in attributes by reference that will hold the parsed values on a successful parse.

Header

```
// forwards to <boost/spirit/home/lex/tokenize_and_parse.hpp>
#include <boost/spirit/include/lex_tokenize_and_parse.hpp>
```

For variadic attributes:

```
// forwards to <boost/spirit/home/lex/tokenize_and_parse_attr.hpp>
#include <boost/spirit/include/lex_tokenize_and_parse_attr.hpp>
```

The variadic attributes version of the API allows one or more attributes to be passed into the API functions. The functions taking two or more attributes are usable when the parser expression is a Sequence only. In this case each of the attributes passed have to match the corresponding part of the sequence.

Also, see Include Structure.

Namespace

Name
`boost::spirit::lex::tokenize`
`boost::spirit::lex::tokenize_and_parse`
`boost::spirit::lex::tokenize_and_phrase_parse`
`boost::spirit::qi::skip_flag::postskip`
`boost::spirit::qi::skip_flag::dont_postskip`

Synopsis

The `tokenize` function is one of the main lexer API functions. It simplifies using a lexer to tokenize a given input sequence. It's main purpose is to use the lexer to tokenize all the input.

Both functions take a pair of iterators spanning the underlying input stream to scan, the lexer object (built from the token definitions), and an (optional) functor being called for each of the generated tokens. If no function object `f` is given, the generated tokens will be discarded.

The functions return `true` if the scanning of the input succeeded (the given input sequence has been successfully matched by the given token definitions).

The argument `f` is expected to be a function (callable) object taking a single argument of the token type and returning a bool, indicating whether the tokenization should be canceled. If it returns `false` the function `tokenize` will return `false` as well.

The `initial_state` argument forces lexing to start with the given lexer state. If this is omitted lexing starts in the `"INITIAL"` state.

```
template <typename Iterator, typename Lexer>
inline bool
tokenize(
    Iterator& first
  , Iterator last
  , Lexer const& lex
  , typename Lexer::char_type const* initial_state = 0);

template <typename Iterator, typename Lexer, typename F>
inline bool
tokenize(
    Iterator& first
  , Iterator last
  , Lexer const& lex
  , F f
  , typename Lexer::char_type const* initial_state = 0);
```

The `tokenize_and_parse` function is one of the main lexer API functions. It simplifies using a lexer as the underlying token source while parsing a given input sequence.

The functions take a pair of iterators spanning the underlying input stream to parse, the lexer object (built from the token definitions) and a parser object (built from the parser grammar definition). Additionally they may take the attributes for the parser step.

The function returns `true` if the parsing succeeded (the given input sequence has been successfully matched by the given grammar).

```
template <typename Iterator, typename Lexer, typename ParserExpr>
inline bool
tokenize_and_parse(
    Iterator& first
  , Iterator last
  , Lexer const& lex
  , ParserExpr const& expr)

template <typename Iterator, typename Lexer, typename ParserExpr
  , typename Attr1, typename Attr2, ..., typename AttrN>
inline bool
tokenize_and_parse(
    Iterator& first
  , Iterator last
  , Lexer const& lex
  , ParserExpr const& expr
  , Attr1 const& attr1, Attr2 const& attr2, ..., AttrN const& attrN);
```

The functions `tokenize_and_phrase_parse` take a pair of iterators spanning the underlying input stream to parse, the lexer object (built from the token definitions) and a parser object (built from the parser grammar definition). The additional skipper parameter will be used as the skip parser during the parsing process. Additionally they may take the attributes for the parser step.

The function returns `true` if the parsing succeeded (the given input sequence has been successfully matched by the given grammar).

```
template <typename Iterator, typename Lexer, typename ParserExpr
  , typename Skipper>
inline bool
tokenize_and_phrase_parse(
    Iterator& first
  , Iterator last
  , Lexer const& lex
  , ParserExpr const& expr
  , Skipper const& skipper
  , BOOST_SCOPED_ENUM(skip_flag) post_skip = skip_flag::postskip);

template <typename Iterator, typename Lexer, typename ParserExpr
  , typename Skipper, typename Attr1, typename Attr2, ..., typename AttrN>
inline bool
tokenize_and_phrase_parse(
    Iterator& first
  , Iterator last
  , Lexer const& lex
  , ParserExpr const& expr
  , Skipper const& skipper
  , Attr1 const& attr1, Attr2 const& attr2, ..., AttrN const& attrN);

template <typename Iterator, typename Lexer, typename ParserExpr
  , typename Skipper, typename Attr1, typename Attr2, ..., typename AttrN>
inline bool
tokenize_and_phrase_parse(
    Iterator& first
  , Iterator last
  , Lexer const& lex
  , ParserExpr const& expr
  , Skipper const& skipper
  , BOOST_SCOPED_ENUM(skip_flag) post_skip
  , Attr1 const& attr1, Attr2 const& attr2, ..., AttrN const& attrN);
```

The maximum number of supported arguments is limited by the preprocessor constant `SPIRIT_ARGUMENTS_LIMIT`. This constant defaults to the value defined by the preprocessor constant `PHOENIX_LIMIT` (which in turn defaults to `10`).

Note

The variadic function with two or more attributes internally combine references to all passed attributes into a `fusion::vector` and forward this as a combined attribute to the corresponding one attribute function.

The `tokenize_and_phrase_parse` functions not taking an explicit `skip_flag` as one of their arguments invoke the passed skipper after a successful match of the parser expression. This can be inhbited by using the other versions of that function while passing `skip_flag::dont_postskip` to the corresponding argument.

Template parameters

Parameter	Description
`Iterator`	`ForwardIterator` pointing to the underlying input sequence to parse.
`Lexer`	A lexer (token definition) object.
`F`	A function object called for each generated token.
`ParserExpr`	An expression that can be converted to a Qi parser.
`Skipper`	Parser used to skip white spaces.
`Attr1`, `Attr2`, ..., `AttrN`	One or more attributes.

Token definition Primitives

This module includes different primitives allowing you to create token definitions. It includes `char_`, character literals, `string`, and string literals.

Module Headers

```
// forwards to <boost/spirit/home/lex/primitives.hpp>
#include <boost/spirit/include/lex_primitives.hpp>
```

Also, see Include Structure.

Tokens Matching Single Characters

Description

The character based token definitions described in this section are:

The `char_` creates token definitions matching single characters. The `char_` token definition is associated `standard` encoding namespace. This is needed when doing basic operations such as forcing lower or upper case and dealing with character ranges.

Header

Module Headers

```
// forwards to <boost/spirit/home/lex/lexer/char_token_def.hpp>
#include <boost/spirit/include/lex_char_token_def.hpp>
```

Also, see Include Structure.

Namespace

Name
`boost::spirit::lit // alias: boost::spirit::lex::lit`
`lex::char_`

Model of

`PrimitiveLexer`

Notation

`ch` Character-class specific character from `standard` character set.

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in `PrimitiveLexer`.

Expression	Description
`ch`	Create a token definition matching the character literal `ch`.
`lit(ch)`	Create a token definition matching the character literal `ch`.
`lex::char_(ch)`	Create a token definition matching the character `ch`.

Example

Advanced

In Depth

Parsers in Depth

This section is not for the faint of heart. In here, are distilled the inner workings of *Spirit.Qi* parsers, using real code from the Spirit library as examples. On the other hand, here is no reason to fear reading on, though. We tried to explain things step by step while highlighting the important insights.

The `Parser` class is the base class for all parsers.

```
template <typename Derived>
struct parser
{
    struct parser_id;
    typedef Derived derived_type;
    typedef qi::domain domain;

    // Requirement: p.parse(f, l, context, skip, attr) -> bool
    //
    //  p:          a parser
    //  f, l:       first/last iterator pair
    //  context:    enclosing rule context (can be unused_type)
    //  skip:       skipper (can be unused_type)
    //  attr:       attribute (can be unused_type)

    // Requirement: p.what(context) -> info
    //
    //  p:          a parser
    //  context:    enclosing rule context (can be unused_type)

    // Requirement: P::template attribute<Ctx, Iter>::type
    //
    //  P:          a parser type
    //  Ctx:        A context type (can be unused_type)
    //  Iter:       An iterator type (can be unused_type)

    Derived const& derived() const
    {
        return *static_cast<Derived const*>(this);
    }
};
```

The `Parser` class does not really know how to parse anything but instead relies on the template parameter `Derived` to do the actual parsing. This technique is known as the "Curiously Recurring Template Pattern" in template meta-programming circles. This inheritance strategy gives us the power of polymorphism without the virtual function overhead. In essence this is a way to implement compile time polymorphism.

The Derived parsers, `PrimitiveParser`, `UnaryParser`, `BinaryParser` and `NaryParser` provide the necessary facilities for parser detection, introspection, transformation and visitation.

Derived parsers must support the following:

bool parse(f, l, context, skip, attr)

`f`, `l` first/last iterator pair

`context` enclosing rule context (can be unused_type)

`skip` skipper (can be unused_type)

`attr` attribute (can be unused_type)

The *parse* is the main parser entry point. *skipper* can be an `unused_type`. It's a type used every where in Spirit to signify "don't-care". There is an overload for *skip* for `unused_type` that is simply a no-op. That way, we do not have to write multiple parse functions for phrase and character level parsing.

Here are the basic rules for parsing:

- The parser returns `true` if successful, `false` otherwise.

- If successful, `first` is incremented N number of times, where N is the number of characters parsed. N can be zero --an empty (epsilon) match.
- If successful, the parsed attribute is assigned to *attr*
- If unsuccessful, `first` is reset to its position before entering the parser function. *attr* is untouched.

void what(context)

`context` enclosing rule context (can be `unused_type`)

The *what* function should be obvious. It provides some information about "what" the parser is. It is used as a debugging aid, for example.

P::template attribute<context>::type

`P` a parser type

`context` A context type (can be unused_type)

The *attribute* metafunction returns the expected attribute type of the parser. In some cases, this is context dependent.

In this section, we will dissect two parser types:

Parsers

`PrimitiveParser` A parser for primitive data (e.g. integer parsing).

`UnaryParser` A parser that has single subject (e.g. kleene star).

Primitive Parsers

For our disection study, we will use a Spirit primitive, the `int_parser` in the boost::spirit::qi namespace.

```
template <
    typename T
  , unsigned Radix = 10
  , unsigned MinDigits = 1
  , int MaxDigits = -1>
struct int_parser_impl
  : primitive_parser<int_parser_impl<T, Radix, MinDigits, MaxDigits> >
{
    // check template parameter 'Radix' for validity
    BOOST_SPIRIT_ASSERT_MSG(
        Radix == 2 || Radix == 8 || Radix == 10 || Radix == 16,
        not_supported_radix, ());

    template <typename Context, typename Iterator>
    struct attribute
    {
        typedef T type;
    };

    template <typename Iterator, typename Context
      , typename Skipper, typename Attribute>
    bool parse(Iterator& first, Iterator const& last
      , Context& /*context*/, Skipper const& skipper
      , Attribute& attr) const
    {
        qi::skip_over(first, last, skipper);
        return extract_int<T, Radix, MinDigits, MaxDigits>
            ::call(first, last, attr);
    }

    template <typename Context>
    info what(Context& /*context*/) const
    {
        return info("integer");
    }
};
```

The `int_parser` is derived from a `PrimitiveParser<Derived>`, which in turn derives from `parser<Derived>`. Therefore, it supports the following requirements:

- The `parse` member function
- The `what` member function
- The nested `attribute` metafunction

parse is the main entry point. For primitive parsers, our first thing to do is call:

```
qi::skip(first, last, skipper);
```

to do a pre-skip. After pre-skipping, the parser proceeds to do its thing. The actual parsing code is placed in `extract_int<T, Radix, MinDigits, MaxDigits>::call(first, last, attr);`

This simple no-frills protocol is one of the reasons why Spirit is fast. If you know the internals of *Spirit.Classic* and perhaps even wrote some parsers with it, this simple Spirit mechanism is a joy to work with. There are no scanners and all that crap.

The *what* function just tells us that it is an integer parser. Simple.

The *attribute* metafunction returns the T template parameter. We associate the `int_parser` to some placeholders for `short_`, `int_`, `long_` and `long_long` types. But, first, we enable these placeholders in namespace boost::spirit:

```
template <>
struct use_terminal<qi::domain, tag::short_> // enables short_
  : mpl::true_ {};
```

```
template <>
struct use_terminal<qi::domain, tag::int_> // enables int_
  : mpl::true_ {};
```

```
template <>
struct use_terminal<qi::domain, tag::long_> // enables long_
  : mpl::true_ {};
```

```
template <>
struct use_terminal<qi::domain, tag::long_long> // enables long_long
  : mpl::true_ {};
```

Notice that `int_parser` is placed in the namespace boost::spirit::qi while these *enablers* are in namespace boost::spirit. The reason is that these placeholders are shared by other Spirit *domains*. *Spirit.Qi*, the parser is one domain. *Spirit.Karma*, the generator is another domain. Other parser technologies may be developed and placed in yet another domain. Yet, all these can potentially share the same placeholders for interoperability. The interpretation of these placeholders is domain-specific.

Now that we enabled the placeholders, we have to write generators for them. The make_xxx stuff (in boost::spirit::qi namespace):

```
template <typename T>
struct make_int
{
    typedef int_parser_impl<T> result_type;
    result_type operator()(unused_type, unused_type) const
    {
        return result_type();
    }
};
```

This one above is our main generator. It's a simple function object with 2 (unused) arguments. These arguments are

1. The actual terminal value obtained by proto. In this case, either a short, int, long_ or long_long. We don't care about this.
2. Modifiers. We also don't care about this. This allows directives such as `no_case[p]` to pass information to inner parser nodes. We'll see how that works later.

Now:

```
template <typename Modifiers>
struct make_primitive<tag::short_, Modifiers> : make_int<short> {};
```

```
template <typename Modifiers>
struct make_primitive<tag::int_, Modifiers> : make_int<int> {};
```

```
template <typename Modifiers>
struct make_primitive<tag::long_, Modifiers> : make_int<long> {};
```

```
template <typename Modifiers>
struct make_primitive<tag::long_long, Modifiers>
  : make_int<boost::long_long_type> {};
```

These, specialize `qi:make_primitive` for specific tags. They all inherit from `make_int` which does the actual work.

Composite Parsers

Let me present the kleene star (also in namespace spirit::qi):

```
template <typename Subject>
struct kleene : unary_parser<kleene<Subject> >
{
    typedef Subject subject_type;

    template <typename Context, typename Iterator>
    struct attribute
    {
        // Build a std::vector from the subject's attribute. Note
        // that build_std_vector may return unused_type if the
        // subject's attribute is an unused_type.
        typedef typename
            traits::build_std_vector<
                typename traits::
                    attribute_of<Subject, Context, Iterator>::type
            >::type
        type;
    };

    kleene(Subject const& subject)
      : subject(subject) {}

    template <typename Iterator, typename Context
      , typename Skipper, typename Attribute>
    bool parse(Iterator& first, Iterator const& last
      , Context& context, Skipper const& skipper
      , Attribute& attr) const
    {
        // create a local value if Attribute is not unused_type
        typedef typename traits::container_value<Attribute>::type
            value_type;
        value_type val = value_type();

        // Repeat while subject parses ok
        while (subject.parse(first, last, context, skipper, val))
        {
            // push the parsed value into our attribute
            traits::push_back(attr, val);
            traits::clear(val);
        }
```

```
        return true;
    }

    template <typename Context>
    info what(Context& context) const
    {
        return info("kleene", subject.what(context));
    }

    Subject subject;
};
```

Looks similar in form to its primitive cousin, the `int_parser`. And, again, it has the same basic ingredients required by `Derived`.

- The nested attribute metafunction
- The parse member function
- The what member function

kleene is a composite parser. It is a parser that composes another parser, its “subject”. It is a `UnaryParser` and subclasses from it. Like `PrimitiveParser`, `UnaryParser<Derived>` derives from `parser<Derived>`.

unary_parser<Derived>, has these expression requirements on Derived:

- p.subject -> subject parser (*p* is a `UnaryParser` parser.)
- P::subject_type -> subject parser type (*P* is a `UnaryParser` type.)

parse is the main parser entry point. Since this is not a primitive parser, we do not need to call `qi::skip(first, last, skipper)`. The *subject*, if it is a primitive, will do the pre-skip. If if it is another composite parser, it will eventually call a primitive parser somewhere down the line which will do the pre-skip. This makes it a lot more efficient than *Spirit.Classic*. *Spirit.Classic* puts the skipping business into the so-called "scanner" which blindly attempts a pre-skip everytime we increment the iterator.

What is the *attribute* of the kleene? In general, it is a `std::vector<T>` where `T` is the attribute of the subject. There is a special case though. If `T` is an `unused_type`, then the attribute of kleene is also `unused_type`. `traits::build_std_vector` takes care of that minor detail.

So, let's parse. First, we need to provide a local attribute of for the subject:

```
typename traits::attribute_of<Subject, Context>::type val;
```

`traits::attribute_of<Subject, Context>` simply calls the subject's `struct attribute<Context>` nested metafunction.

val starts out default initialized. This val is the one we'll pass to the subject's parse function.

The kleene repeats indefinitely while the subject parser is successful. On each successful parse, we `push_back` the parsed attribute to the kleen's attribute, which is expected to be, at the very least, compatible with a `std::vector`. In other words, although we say that we want our attribute to be a `std::vector`, we try to be more lenient than that. The caller of kleene's parse may pass a different attribute type. For as long as it is also a conforming STL container with `push_back`, we are ok. Here is the kleene loop:

```
while (subject.parse(first, last, context, skipper, val))
{
    // push the parsed value into our attribute
    traits::push_back(attr, val);
    traits::clear(val);
}
return true;
```

Take note that we didn't call attr.push_back(val). Instead, we called a Spirit provided function:

```
traits::push_back(attr, val);
```

This is a recurring pattern. The reason why we do it this way is because attr **can** be `unused_type`. `traits::push_back` takes care of that detail. The overload for unused_type is a no-op. Now, you can imagine why Spirit is fast! The parsers are so simple and the generated code is as efficient as a hand rolled loop. All these parser compositions and recursive parse invocations are extensively inlined by a modern C++ compiler. In the end, you get a tight loop when you use the kleene. No more excess baggage. If the attribute is unused, then there is no code generated for that. That's how Spirit is designed.

The *what* function simply wraps the output of the subject in a "kleene“... "”".

Ok, now, like the `int_parser`, we have to hook our parser to the qi engine. Here's how we do it:

First, we enable the prefix star operator. In proto, it's called the "dereference":

```
template <>
struct use_operator<qi::domain, proto::tag::dereference> // enables *p
  : mpl::true_ {};
```

This is done in namespace `boost::spirit` like its friend, the `use_terminal` specialization for our `int_parser`. Obviously, we use *use_operator* to enable the dereference for the qi::domain.

Then, we need to write our generator (in namespace qi):

```
template <typename Elements, typename Modifiers>
struct make_composite<proto::tag::dereference, Elements, Modifiers>
  : make_unary_composite<Elements, kleene>
{};
```

This essentially says; for all expressions of the form: `*p`, to build a kleene parser. Elements is a Boost.Fusion sequence. For the kleene, which is a unary operator, expect only one element in the sequence. That element is the subject of the kleene.

We still don't care about the Modifiers. We'll see how the modifiers is all about when we get to deep directives.

Customization of Spirit's Attribute Handling

Why do we need Attribute Customization Points

Important

Before you read on please be aware that the interfaces described in this section are not finalized and may change in the future without attempting to be backwards compatible. We document the customization point interfaces anyways as we think they are important. Understanding customization points helps understanding Spirit. Additionally they prove to be powerful tools enabling full integration of the user's data structures with *Qi's* parsers and *Karma's* generators.

Spirit has been written with extensibility in mind. It provides many different attribute customization points allowing to integrate custom data types with the process of parsing in *Spirit.Qi* or output generation with *Spirit.Karma*. All attribute customization points are exposed using a similar technique: full or partial template specialization. Spirit generally implements the main template, providing a default implementation. You as the user have to provide a partial or full specialization of this template for the data types you want to integrate with the library. In fact, the library uses these customization points itself for instance to handle the magic of the `unused_type` attribute type.

Here is an example showing the `container_value` customization point used by different parsers (such as Kleene, Plus, etc.) to find the attribute type to be stored in a supplied STL container:

```
template <typename Container, typename Enable/* = void*/>
struct container_value
  : detail::remove_value_const<typename Container::value_type>
{};
```

This template is instantiated by the library at the appropriate places while using the supplied container type as the template argument. The embedded `type` is used as the attribute type while parsing the elements to be store in that container.

The following example shows the predefined specialization for `unused_type`:

```
template <>
struct container_value<unused_type>
{
    typedef unused_type type;
};
```

which defines its embedded `type` to be `unused_type` as well, this way propagating the 'don't care' attribute status to the embedded parser.

All attribute customization points follow the same scheme. The last template parameter is always `typename Enable = void` allowing to apply SFINAE for fine grained control over the template specialization process. But most of the time you can safely forget about its existence.

The following sections will describe all customization points, together with a description which needs to be specialized for what purpose.

The Usage of Customization Points

The different customizations points are used by different parts of the library. Part of the customizations points are used by both, *Spirit.Qi* and *Spirit.Karma*, whereas others are specialized to be applied for one of the sub-libraries only. We will explain when a specific customization point needs to be implemented and, equally important, which customization points need to be implemented at the same time. Often it is not sufficient to provide a specialization for one single customization point only, in this case you as the user have to provide all necessary customizations for your data type you want to integrate with the library.

Determine if a Type Should be Treated as a Container (Qi and Karma)

is_container

The template `is_container` is a template meta-function used as an attribute customization point. It is invoked by the *Qi* Sequence (>>) and *Karma* Sequence (<<) operators in order to determine whether a supplied attribute can potentially be treated as a container.

Header

```
#include <boost/spirit/home/support/container.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Container, typename Enable>
struct is_container
{
    typedef <unspecified> type;
};
```

Template parameters

Parameter	Description	Default
`Container`	The type, `Container` which needs to be tested whether it has to be treated as a container	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `is_container` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

`C`	A type to be tested whether it needs to be treated as a container.
`T1`, `T2`, ...	Arbitrary types

Expression Semantics

Expression	Semantics
`is_container<C>::type`	Result of the metafunction that evaluates to `mpl::true_` if a given type, `C`, is to be treated as a container, `mpl::false_` otherwise (See MPL Boolean Constant).

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the conditions for which the corresponding specializations will evaluate to `mpl::true_` (see MPL Boolean Constant):

Template Parameters	Value
`T`	Returns `mpl::true_` if `T` has the following embedded types defined: `value_type`, `iterator`, `size_type`, and`reference`. Otherwise it will return `mpl::false_`.
`boost::optional<T>`	Returns `is_container<T>::type`
`boost::variant<T1, T2, ...>`	Returns `mpl::true_` if at least one of the `is_container<TN>::type` returns `mpl::true_` (where `TN` is `T1`, `T2`, ...). Otherwise it will return `mpl::false_`.
`unused_type`	Returns `mpl::false_`.

When to implement

The customization point `is_container` needs to be implemented for a specific type whenever this type is to be used as an attribute in place of a STL container. It is applicable for parsers (*Spirit.Qi*) and generators (*Spirit.Karma*). As a rule of thumb: it has to be implemented whenever a certain type is to be passed as an attribute to a parser or a generator normally exposing a STL container, `C` and if the type does not expose the interface of a STL container (i.e. `is_container<C>::type` would normally return `mpl::false_`). These components have an attribute propagation rule in the form:

```
a: A --> Op(a): vector<A>
```

where `Op(a)` stands for any meaningful operation on the component `a`.

Related Attribute Customization Points

If this customization point is implemented, the following other customization points might need to be implemented as well.

Name	When to implement
`container_value`	Needs to be implemented whenever `is_container` is implemented.
`push_back_container`	Qi: List, Kleene, Plus, Repeat.
`container_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`begin_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`end_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`deref_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`next_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`compare_iterators`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.

Example

For examples of how to use the customization point `is_container` please see here: embedded_container_example, use_as_container, and counter_example.

Transform an Attribute to a Different Type (Qi and Karma)

transform_attribute

The template `transform_attribute` is a type used as an attribute customization point. It is invoked by *Qi* `rule` and `attr_cast`, and *Karma* `rule` and `attr_cast`. It is used to automatically transform the user provided attribute to the attribute type expected by the right hand side component (for `rule`) or the embedded component (for `attr_cast`).

Module Headers

```
#include <boost/spirit/home/support/attributes.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Exposed, typename Transformed, typename Enable>
struct transform_attribute
{
    typedef <unspecified> type;
    static type pre(Exposed& val);
    static void post(Exposed& val, type attr);    // Qi only
};
```

Template parameters

Parameter	Description	Default
`Exposed`	The attribute type supplied to the component which needs to be transformed.	none
`Transformed`	The attribute type expected by the component to be provided as the result of the transformation.	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `transform_attribute` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

Notation

`Exposed` The type, `Exposed` is the type of the attribute as passed in by the user.

`Transformed` The type, `Transformed` is the type of the attribute as passed along to the right hand side of the `rule` (embedded component of `attr_cast`).

`exposed` An instance of type `Exposed`.

`transformed` An instance of type `Transformed`.

Expression Semantics

Expression	Semantics
`transform_attribute<Exposed, Transformed>::type`	Evaluates to the type to be used as the result of the transformation (to be passed to the right hand side of the `rule` or to the embedded component of the `attr_cast`. Most of the time this is equal to `Transformed`, but in other cases this might evaluate to `Transformed&` instead avoiding superfluous object creation.
`type transform_attribute<Exposed, Transformed>::pre(exposed)`	Do `pre`-transformation before invoking the right hand side component for `rule` (or the embedded component for `attr_cast`). This takes the attribute supplied as by the user (of type `Exposed`) and returns the attribute to be passed down the component hierarchy (of the type as exposed by the metafunction `type`). This function will be called in *Qi* and for *Karma*.
`void transform_attribute<Exposed, Transformed>::post(exposed, transformed)`	Do `post`-transformation after the invocation of the right hand side component for `rule` (or the embedded component for `attr_cast`). This takes the original attribute as supplied by the user and the attribute as returned from the right hand side (embedded) component and is expected to propagate the result back into the supplied attribute instance. This function will be called in *Qi* only.

Predefined Specializations

Template parameters	Semantics
`Exposed`, `Transformed`	`type` evaluates to `Transformed`, `pre()` returns a new instance of `Transformed` constructed from the argument of type `Exposed`, `post()` assigns `transformed` to `exposed`.
`Exposed&`, `Transformed`	`type` evaluates to `Transformed`, `pre()` returns a new instance of `Transformed` constructed from the argument of type `Exposed`, `post()` assigns `transformed` to `exposed`.
`Attrib&`, `Attrib`	`type` evaluates to `Attrib&`, `pre()` returns it's argument, `post()` does nothing.
`Exposed const`, `Transformed`	(usind in *Karma* only) `type` evaluates to `Transformed`, `pre()` returns it's argument, `post()` is not implemented.
`Attrib const&`, `Attrib`	(usind in *Karma* only) `type` evaluates to `Attrib const&`, `pre()` returns it's argument, `post()` is not implemented.
`Attrib const`, `Attrib`	(usind in *Karma* only) `type` evaluates to `Attrib const&`, `pre()` returns it's argument, `post()` is not implemented.
`unused_type`, `Attrib`	`type` evaluates to `unused_type`, `pre()` and `post()` do nothing.
`Attrib`, `unused_type`	`type` evaluates to `unused_type`, `pre()` and `post()` do nothing.

When to implement

The customization point `transform_attribute` needs to be implemented for a specific pair of types whenever the attribute type supplied to a `rule` or `attr_cast` cannot automatically transformed to the attribute type expected by the right hand side of the `rule` (embedded component of the `attr_cast`) because the default implementation as shown above is not applicable. Examples for this could be that the type `Transformed` is not constructible from the type `Exposed`.

Example

TBD

Store a Parsed Attribute Value (Qi)

After parsing input and generting an attribute value this value needs to assigned to the attribute instance provided by the user. The customization points `assign_to_attribute_from_iterators` and `assign_to_attribute_from_value` are utilized to adapt this assignment to the concrete type to be assigned. This section describes both.

Store an Attribute after a Parser Produced a Pair of Iterators (Qi)

assign_to_attribute_from_iterators

The template `assign_to_attribute_from_iterators` is a type used as an attribute customization point. It is invoked by the those *Qi* parsers not producing any attribute value but returning a pair of iterators pointing to the matched input sequence. It is used to either store the iterator pair into the attribute instance provided by the user or to convert the iterator pair into an attribute as provided by the user.

Module Headers

```
#include <boost/spirit/home/qi/detail/assign_to.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Attrib, typename Iterator, typename Enable>
struct assign_to_attribute_from_iterators
{
    static void call(Iterator const& first, Iterator const& last, Attrib& attr);
};
```

Template parameters

Parameter	Description	Default
`Attrib`	The type, `Attrib` is the type of the attribute as passed in by the user.	none
`Iterator`	The type, `Iterator` is the type of the iterators as produced by the parser.	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `assign_to_attribute_from_value` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

Notation

`Attrib`	A type to be used as the target to store the attribute value in.
`attr`	A attribute instance of type `Attrib`.
`Iterator`	The iterator type used by the parser. This type usually corresponds to the iterators as passed in by the user.
`begin`, `end`	Iterator instances of type `Iterator` pointing to the begin and the end of the matched input sequence.

Expression Semantics

Expression	Semantics
`assign_to_attribute_from_iterators<Attrib, Iterator>::call(b, e, attr)`	Use the iterators `begin` and `end` to initialize the attribute `attr`.

Predefined Specializations

Template Parameters	Semantics
`Attrib`, `Iterator`	Execute an assignment `attr = Attrib(begin, end)`.
`unused_type`, `T`	Do nothing.

When to implement

The customization point `assign_to_attribute_from_iterators` needs to be implemented for a specific type whenever the default implementation as shown above is not applicable. Examples for this could be that the type `Attrib` is not constructible from the pair of iterators.

Example

TBD

Store an Attribute Value after a Parser Produced a Value (Qi)

assign_to_attribute_from_value

The template `assign_to_attribute_from_value` is a type used as an attribute customization point. It is invoked by the all primitive *Qi* parsers in order to store a parsed attribute value into the attribute instance provided by the user.

Module Headers

```
#include <boost/spirit/home/qi/detail/assign_to.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Attrib, typename T, typename Enable>
struct assign_to_attribute_from_value
{
    static void call(T const& val, Attrib& attr);
};
```

Template parameters

Parameter	Description	Default
`Attrib`	The type, `Attrib` is the type of the attribute as passed in by the user.	none
`T`	The type, `T` is the type of the attribute instance as produced by the parser.	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `assign_to_attribute_from_value` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

Notation

`Attrib` A type to be used as the target to store the attribute value in.

`attr` A attribute instance of type `Attrib`.

`T` A type as produced by the parser. The parser temporarily stores its parsed values using this type.

`t` A attribute instance of type `T`.

Expression Semantics

Expression	Semantics
`assign_to_attribute_from_value<Attrib, T>::call(t, attr)`	Copy (assign) the value, `t` to the attribute `attr`.

Predefined Specializations

Template Parameters	Semantics
`Attrib`, `T`	Assign the argument `t` to `attr`.
`unused_type`, `T`	Do nothing.

When to implement

The customization point `assign_to_attribute_from_value` needs to be implemented for a specific type whenever the default implementation as shown above is not applicable. Examples for this could be that the type `Attrib` is not copy constructible.

Example

TBD

Store Parsed Attribute Values into a Container (Qi)

In order to customize Spirit to accept a given data type as a container for elements parsed by any of the repetitive parsers (Kleene, Plus, List, and Repeat) two attribute customization points have to be specialized: `container_value` and `push_back_container`. This section describes both.

Determine the Type to be Stored in a Container (Qi)

container_value

The template `container_value` is a template meta function used as an attribute customization point. It is invoked by the *Qi* repetitive parsers (Kleene, Plus, List, and Repeat) to determine the type to store in a container.

Module Headers

```
#include <boost/spirit/home/support/container.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Container, typename Enable>
struct container_value
{
    typedef <unspecified> type;
};
```

Template parameters

Parameter	Description	Default
`Container`	The type, `Container` needs to be tested whether it has to be treated as a container	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `container_value` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

`C`	A type to be tested whether it needs to be treated as a container.
`T1`, `T2`, ...	Arbitrary types

Expression Semantics

Expression	Semantics
`container_value<C>::type`	Metafunction that evaluates to the type to be stored in a given container type, `C`.

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types exposed and the corresponding semantics:

Template Parameters	Value
`C`	The non-const `value_type` of the given container type, `C`.
`boost::optional<C>`	Returns `container_value<C>::type`
`boost::variant<T1, T2, ...>`	Returns `container_value<TN>::value` for the first `TN` (out of `T1`, `T2`, ...) for which `is_container<TN>::type` evaluates to `mpl::true_`. Otherwise it will return `unused_type`.
`unused_type`	Returns `unused_type`.

When to implement

The customization point `is_container` needs to be implemented for a specific type whenever this type is to be used as an attribute in place of a STL container. It is applicable for parsers (*Spirit.Qi*) only. As a rule of thumb: it has to be implemented whenever a

certain type is to be passed as an attribute to a parser normally exposing a STL container and if the type does not expose the interface of a STL container (i.e. no embedded typedef for `value_type`). These components have an attribute propagation rule in the form:

```
a: A --> Op(a): vector<A>
```

where `Op(a)` stands for any meaningful operation on the component `a`.

Related Attribute Customization Points

If this customization point is implemented, the following other customization points might need to be implemented as well.

Name	When to implement
`push_back_container`	Qi: List, Kleene, Plus, Repeat.
`clear_value`	Qi: List, Kleene, Plus, Repeat.

Example

TBD

Store a Parsed Attribute Value into a Container (Qi)

push_back_container

The template `push_back_container` is a type used as an attribute customization point. It is invoked by the *Qi* repetitive parsers (Kleene, Plus, List, and Repeat) to store a parsed attribute value into a container.

Module Headers

```
#include <boost/spirit/home/support/container.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Container, typename Attrib, typename Enable>
struct push_back_container
{
    static void call(Container& c, Attrib const& val);
};
```

Template parameters

Parameter	Description	Default
`Container`	The type, `Container` needs to be tested whether it has to be treated as a container	none
`Attrib`	The type, `Attrib` is the one returned from the customization point `container_value` and represents the attribute value to be stored in the container of type `Container`.	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `push_back_container` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

`C`	A type to be used as a container to store attribute values in.
`c`	A container instance of type `C`. [`Attrib` A type to be used as a container to store attribute values in.
`attr`	A attribute instance of type `Attrib`.
`T1`, `T2`, ...	Arbitrary types

Expression Semantics

Expression	Semantics
`push_back_container<C, Attrib>::call(c, attr)`	Static function that is invoked whenever an attribute value, `attr` needs to be stored into the container instance `c`.

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types exposed and the corresponding semantics:

Template Parameters	Value
`C`, `Attrib`	Store the provided attribute instance `attr` into the given container `c` using the function call `c.insert(c.end(), attr)`.
`boost::optional<C>`, `Attrib`	If the provided instance of `boost::optional<>` is not initialized, invoke the appropriate initialization and afterwards apply the customization point `push_back_container<C, Attrib>`, treating the instance held by the optional (of type `C`) as the container to store the attribute in.
`boost::variant<T1, T2, ...>`, `Attrib`	If the instance of the variant currently holds a value with a type, `TN`, for which `is_container<TN>::type` evaluates to `mpl::true_`, this customization point specialization will apply `push_back_container<TN, Attrib>`, treating the instance held by the variant (of type `TN`) as the container to store the attribute in. Otherwise it will raise an assertion.
`unused_type`	Do nothing.

When to Implement

The customization point `push_back_container` needs to be implemented for a specific type whenever this type is to be used as an attribute in place of a STL container. It is applicable for parsers (*Spirit.Qi*) only. As a rule of thumb: it has to be implemented whenever a certain type is to be passed as an attribute to a parser normally exposing a STL container and if the type does not expose the interface of a STL container (i.e. no function being equivalent to `c.insert(c.end(), attr)`. These components have an attribute propagation rule in the form:

```
a: A --> Op(a): vector<A>
```

where `Op(a)` stands for any meaningful operation on the component `a`.

Related Attribute Customization Points

If this customization point is implemented, the following other customization points might need to be implemented as well.

Name	When to implement
`container_value`	Qi: List, Kleene, Plus, Repeat.
`clear_value`	Qi: List, Kleene, Plus, Repeat.

Example

TBD

Re-Initialize an Attribute Value before Parsing (Qi)

clear_value

The template `clear_value` is a type used as an attribute customization point. It is invoked by the *Qi* repetitive parsers (Kleene, Plus, List, and Repeat) in order to re-initialize the attribute instance passed to the embedded parser after it has been stored in the provided container. This re-initialized attribute instance is reused during the next iteration of the repetitive parser.

Module Headers

```
#include <boost/spirit/home/support/attributes.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Attrib, typename Enable>
struct clear_value
{
    static void call(Attrib& val);
};
```

Template parameters

Parameter	Description	Default
`Attrib`	The type, `Attrib` of the attribute to be re-initialized.	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `clear_value` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

Notation

`Attrib`	A type to be used as a container to store attribute values in.
`attr`	A attribute instance of type `Attrib`.
`T1`, `T2`, ...	Arbitrary types

Expression Semantics

Expression	Semantics
`clear_value<Attrib>::call(Attrib& attr)`	Re-initialize the instance referred to by `attr` in the most efficient way.

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types exposed and the corresponding semantics:

Template Parameters	Value
`Attrib`	Re-initialize using assignment of default constructed value.
Any type `T` for which `is_container<>::type` is `mpl::true_`	Call the member function `attr.clear()` for the passed attribute instance.
`boost::optional<Attrib>`	Clear the `optional` instance and leave it uninitialized.
`boost::variant<T1, T2, ...>`	Invoke the `clear_value` customization point for the currently held value.
`fusion::tuple<T1, T2, ...>`	Invoke the `clear_value` customization point for all elements of the tuple.
`unused_type`	Do nothing.

When to Implement

The customization point `clear_value` needs to be implemented for a specific type whenever this type is to be used as an attribute to be stored into a STL container and if the type cannot be re-initialized using one of the specializations listed above. Examples for this might be types not being default constructible or container types not exposing a member function `clear()`.

Example

TBD

Extract an Attribute Value to Generate Output (Karma)

extract_from

Before generating output for a value this value needs to extracted from the attribute instance provided by the user. The customization point `extract_from` is utilized to adapt this extraction for any data type possibly used to store the values to output.

Module Headers

```
#include <boost/spirit/home/karma/detail/extract_from.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Attrib, typename Enable>
struct extract_from_attribute
{
    typedef <unspecified> type;

    template <typename Context>
    static type call(Attrib const& attr, Context& context);
};
```

Template parameters

Parameter	Description	Default
`Attrib`	The type, `Attrib` of the attribute to be used to generate output from.	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `clear_value` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`
`Context`	This is the type of the current generator execution context.	

Notation

Notation

`Attrib` A type to be used to generate output from.

`attr` A attribute instance of type `Attrib`.

Expression Semantics

Expression	Semantics
`extract_from_attribute<Attrib>::call(attr, ctx)`	Extract the value to generate output from and return it to the caller.

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types exposed and the corresponding semantics:

Template Parameters	Value
`Attrib`	The exposed typedef `type` is defined to `Attrib const&`. The function `call()` returns the argument by reference without change.
`boost::optional<Attrib>`	The exposed typedef `type` is defined to `Attrib const&`. The function `call()` returns the value held by the `optional<>` argument by reference without change.
`boost::reference_wrapper<Attrib>`	The exposed typedef `type` is defined to `Attrib const&`. The function `call()` returns the value held by the `reference_wrapper<>` argument by reference without change.
`unused_type`	The exposed typedef `type` is defined to `unused_type`. The function `call()` returns an instance of `unused_type`.

When to implement

The customization point `extract_from_attribute` needs to be implemented for a specific type whenever the default implementation as shown above is not applicable. Examples for this could be that the type to be extracted is different from `Attrib` and is not copy constructible.

Example

TBD

Extract Attribute Values to Generate Output from a Container (Karma)

Determine the Type of the Iterator of a Container (Karma)

container_iterator

The template `container_iterator` is a template meta-function used as an attribute customization point. It is invoked by the *Karma* repetitive generators (such as List (%), Kleene (unary *), Plus (unary +), and Repeat) in order to determine the type of the iterator to use to iterate over the items to be exposed as the elements of a container.

Module Headers

```
#include <boost/spirit/home/support/container.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Container, typename Enable>
struct container_iterator
{
    typedef <unspecified> type;
};
```

Template parameters

Parameter	Description	Default
`Container`	The type, `Container` for which the iterator type has to be returned	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `container_iterator` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

`C` A container type the iterator type needs to be evaluated for.

Expression Semantics

Expression	Semantics
`container_iterator<C>::type`	Result of the metafunction that evaluates the type to be used as the iterator for accessing all elements of a container, `C`.

The returned type conceptually needs to be equivalent to a standard forward iterator. But it does not have to expose the standardized interface. If this customization point is implemented for a certain container type, all related customization points need to be implemented as well (see Related Attribute Customization Points below). This encapsulates the specific iterator interface required for a given type. The minimal requirements for a type to be exposed as an iterator in this context are:

- it needs to be comparable for equality (see `compare_iterators`),
- it needs to be incrementable (see `next_iterator`),
- it needs to be dereferencible (see `deref_iterator`).

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types returned by the embedded typedef `type`:

Template Parameters	Value
`C`	Returns `C::iterator`.
`C const`	Returns `C::const_iterator`.
`unused_type`	Returns `unused_type const*`.

When to implement

The customization point `container_iterator` needs to be implemented for a specific type whenever this type is to be used as an attribute in place of a STL container. It is applicable for generators (*Spirit.Karma*) only. As a rule of thumb: it has to be implemented whenever a certain type is to be passed as an attribute to a generator normally exposing a STL container, `C` and if the type does not expose the interface of a STL container (i.e. `is_container<C>::type` would normally return `mpl::false_`).

Related Attribute Customization Points

If this customization point is implemented, the following other customization points might need to be implemented as well.

Name	When to implement
`is_container`	Needs to be implemented whenever a type is to be used as a container attribute in *Karma*.
`container_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`begin_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`end_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`deref_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`next_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`compare_iterators`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.

Example

Here are the header files needed to make the example code below compile:

```
#include <boost/spirit/include/karma.hpp>
#include <iostream>
#include <vector>
```

The example (for the full source code please see here: customize_embedded_container.cpp) uses the data structure

```
namespace client
{
    struct embedded_container
    {
        // expose the iterator of the embedded vector as our iterator
        typedef std::vector<int>::const_iterator iterator;

        // expose the type of the held data elements as our type
        typedef std::vector<int>::value_type type;

        // this is the vector holding the actual elements we need to generate
        // output from
        std::vector<int> data;
    };
}
```

as a direct container attribute to the List (%) generator. In order to make this data structure compatible we need to specialize a couple of attribute customization points: `is_container`, `container_iterator`, `begin_container`, and `end_container`. As you can see the specializations simply expose the embedded `std::vector<int>` as the container to use. We don't need to specialize the

customization points related to iterators (`deref_iterator`, `next_iterator`, and `compare_iterators`) as we expose a standard iterator and the default implementation of these customizations handles standard iterators out of the box.

```
// All specializations of attribute customization points have to be placed into
// the namespace boost::spirit::traits.
//
// Note that all templates below are specialized using the 'const' type.
// This is necessary as all attributes in Karma are 'const'.
namespace boost { namespace spirit { namespace traits
{
    // The specialization of the template 'is_container<>' will tell the
    // library to treat the type 'client::embedded_container' as a
    // container holding the items to generate output from.
    template <>
    struct is_container<client::embedded_container const>
      : mpl::true_
    {};

    // The specialization of the template 'container_iterator<>' will be
    // invoked by the library to evaluate the iterator type to be used
    // for iterating the data elements in the container. We simply return
    // the type of the iterator exposed by the embedded 'std::vector<int>'.
    template <>
    struct container_iterator<client::embedded_container const>
    {
        typedef client::embedded_container::iterator type;
    };

    // The specialization of the templates 'begin_container<>' and
    // 'end_container<>' below will be used by the library to get the iterators
    // pointing to the begin and the end of the data to generate output from.
    // These specializations simply return the 'begin' and 'end' iterators as
    // exposed by the embedded 'std::vector<int>'.
    //
    // The passed argument refers to the attribute instance passed to the list
    // generator.
    template <>
    struct begin_container<client::embedded_container const>
    {
        static client::embedded_container::iterator
        call(client::embedded_container const& d)
        {
            return d.data.begin();
        }
    };

    template <>
    struct end_container<client::embedded_container const>
    {
        static client::embedded_container::iterator
        call(client::embedded_container const& d)
        {
            return d.data.end();
        }
    };
}}}
```

The last code snippet shows an example using an instance of the data structure `client::embedded_container` to generate output from a List (%) generator:

```
client::embedded_container d1;    // create some test data
d1.data.push_back(1);
d1.data.push_back(2);
d1.data.push_back(3);

// use the instance of an 'client::embedded_container' instead of a
// STL vector
std::cout << karma::format(karma::int_ % ", ", d1) << std::endl;   // prints: '1, 2, 3'
```

As you can see, the specializations for the customization points as defined above enable the seemless integration of the custom data structure without having to modify the output format or the generator itself.

For other examples of how to use the customization point `container_iterator` please see here: use_as_container and counter_example.

Get the Iterator pointing to the Begin of a Container Attribute

begin_container

The template `begin_container` is a type used as an attribute customization point. It is invoked by the *Karma* repetitive generators (such as List (%), Kleene (unary *), Plus (unary +), and Repeat) in order to get an iterator pointing to the first element of the container holding the attributes to generate output from.

Module Headers

```
#include <boost/spirit/home/support/container.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Container, typename Enable>
struct begin_container
{
    static typename container_iterator<Container>::type
    call(Container& c);
};
```

Template parameters

Parameter	Description	Default
`Container`	The type, `Container` for which the iterator pointing to the first element has to be returned	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `begin_container` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

`C` A container type the begin iterator needs to be returned for.

`c` An instance of a container, `C`.

Expression Semantics

Expression	Semantics
`begin_container<C>::call(c)`	Return the iterator usable to dereference the first element of the given container, `c`. The type of the returned iterator is expected to be the same as the type returned by the customization point `container_iterator`.

The returned instance conceptually needs to be equivalent to a standard forward iterator. But it does not have to expose the standardized interface. If this customization point is implemented for a certain container type, all related customization points need to be implemented as well (see Related Attribute Customization Points below). This encapsulates the specific iterator interface required for a given type. The minimal requirements for a type to be exposed as an iterator in this context are:

- it needs to be comparable for equality (see `compare_iterators`),
- it needs to be incrementable (see `next_iterator`),
- it needs to be dereferencible (see `deref_iterator`).

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types returned by the embedded typedef `type`:

Template Parameters	Value
`C`	Returns `c.begin()`.
`C const`	Returns `c.begin()`.
`unused_type`	Returns `&unused`.

When to implement

The customization point `begin_container` needs to be implemented for a specific type whenever this type is to be used as an attribute in place of a STL container. It is applicable for generators (*Spirit.Karma*) only. As a rule of thumb: it has to be implemented whenever a certain type is to be passed as an attribute to a generator normally exposing a STL container, `C` and if the type does not expose the interface of a STL container (i.e. `is_container<C>::type` would normally return `mpl::false_`).

Related Attribute Customization Points

If this customization point is implemented, the following other customization points might need to be implemented as well.

Name	When to implement
`is_container`	Needs to be implemented whenever a type is to be used as a container attribute in *Karma*.
`container_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`begin_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`end_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`deref_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`next_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`compare_iterators`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.

Example

For examples of how to use the customization point `begin_container` please see here: embedded_container_example, use_as_container, and counter_example.

Get the Iterator pointing to the End of a Container Attribute

end_container

The template `end_container` is a type used as an attribute customization point. It is invoked by the *Karma* repetitive generators (such as List (%), Kleene (unary *), Plus (unary +), and Repeat) in order to get an iterator pointing to the end of the container holding the attributes to generate output from.

Module Headers

```
#include <boost/spirit/home/support/container.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Container, typename Enable>
struct end_container
{
    static typename container_iterator<Container>::type
    call(Container& c);
};
```

Template parameters

Parameter	Description	Default
`Container`	The type, `Container` for which the iterator pointing to the first element has to be returned	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `end_container` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

`C` A container type the end iterator needs to be returned for.

`c` An instance of a container, `C`.

Expression Semantics

Expression	Semantics
`end_container<C>::call(c)`	Return the iterator usable to compare a different iterator with in order to detect whether the other iterator reached the end of the given container, `c`. The type of the returned iterator is expected to be the same as the type returned by the customization point `container_iterator`.

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types returned by the embedded typedef `type`:

Template Parameters	Value
`C`	Returns `c.end()`.
`C const`	Returns `c.end()`.
`unused_type`	Returns `&unused`.

When to implement

The customization point `end_container` needs to be implemented for a specific type whenever this type is to be used as an attribute in place of a STL container. It is applicable for generators (*Spirit.Karma*) only. As a rule of thumb: it has to be implemented whenever a certain type is to be passed as an attribute to a generator normally exposing a STL container, `C` and if the type does not expose the interface of a STL container (i.e. `is_container<C>::type` would normally return `mpl::false_`).

Related Attribute Customization Points

If this customization point is implemented, the following other customization points might need to be implemented as well.

Name	When to implement
`is_container`	Needs to be implemented whenever a type is to be used as a container attribute in *Karma*.
`container_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`begin_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`end_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`deref_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`next_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`compare_iterators`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.

Example

For examples of how to use the customization point `end_container` please see here: embedded_container_example, use_as_container, and counter_example.

Increment the Iterator pointing into a Container Attribute

next_iterator

The template `next_iterator` is a type used as an attribute customization point. It is invoked by the *Karma* repetitive generators (such as List (%), Kleene (unary *), Plus (unary +), and Repeat) in order to get an iterator pointing to the next element of a container holding the attributes to generate output from.

Module Headers

```
#include <boost/spirit/home/support/container.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Iterator, typename Enable>
struct next_iterator
{
    static void call(Iterator& it);
};
```

Template parameters

Parameter	Description	Default
`Iterator`	The type, `Iterator` of the iterator to increment. This is the same as the type returned by the customization point `container_iterator`.	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `next_iterator` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

`Iterator` An iterator type.

`it` An instance of an iterator, `Iterator`.

`C` A container type a iterator type, `Iterator` belongs to.

Expression Semantics

Expression	Semantics
`next_iterator<Iterator>::call(it)`	Increment the iterator pointing so that it is pointing to the next element.

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types returned by the embedded typedef `type`:

Template Parameters	Value
`Iterator`	Executes `++it`.
`unused_type const*`	Does nothing.

When to implement

The customization point `next_iterator` needs to be implemented for a specific iterator type whenever the container this iterator belongs to is to be used as an attribute in place of a STL container. It is applicable for generators (*Spirit.Karma*) only. As a rule of thumb: it has to be implemented whenever a certain iterator type belongs to a container which is to be passed as an attribute to a generator normally exposing a STL container, `C` and if the container type does not expose the interface of a STL container (i.e. `is_container<C>::type` would normally return `mpl::false_`).

Related Attribute Customization Points

If this customization point is implemented, the following other customization points might need to be implemented as well.

Name	When to implement
`is_container`	Needs to be implemented whenever a type is to be used as a container attribute in *Karma*.
`container_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`begin_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`end_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`deref_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`next_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`compare_iterators`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.

Example

Here are the header files needed to make the example code below compile:

```
#include <boost/spirit/include/karma.hpp>
#include <iostream>
#include <string>
#include <vector>
```

The example (for the full source code please see here: customize_use_as_container.cpp) uses the data structure

```
namespace client
{
    struct use_as_container
    {
        // Expose a pair holding a pointer to the use_as_container and to the
        // current element as our iterator.
        // We intentionally leave out having it a 'operator==()' to demonstrate
        // the use of the 'compare_iterators' customization point.
        struct iterator
        {
            iterator(use_as_container const* container, int const* current)
              : container_(container), current_(current)
            {}

            use_as_container const* container_;
            int const* current_;
        };

        // expose 'int' as the type of each generated element
        typedef int type;

        use_as_container(int value1, int value2, int value3)
          : value1_(value1), value2_(value2), value3_(value3)
        {}

        int value1_;
        std::string dummy1_;    // insert some unrelated data
        int value2_;
        std::string dummy2_;    // insert some more unrelated data
        int value3_;
    };
}
```

as a direct attribute to the List (%) generator. This type does not expose any of the interfaces of an STL container. It does not even expose the usual semantics of a container. The purpose of this artifical example is to demonstrate how the customization points can be used to expose independent data elements as a single container. The example shows how to enable its use as an attribute to *Karma's* repetitive generators.

In order to make this data structure compatible we need to specialize a couple of attribute customization points: `is_container`, `container_iterator`, `begin_container`, and `end_container`. In addition, we specialize all of the iterator related customization points as well: `deref_iterator`, `next_iterator`, and `compare_iterators`.

```
// All specializations of attribute customization points have to be placed into
// the namespace boost::spirit::traits.
//
// Note that all templates below are specialized using the 'const' type.
// This is necessary as all attributes in Karma are 'const'.
namespace boost { namespace spirit { namespace traits
{
    // The specialization of the template 'is_container<>' will tell the
    // library to treat the type 'client::use_as_container' as a
    // container holding the items to generate output from.
    template <>
    struct is_container<client::use_as_container const>
      : mpl::true_
    {};

    // The specialization of the template 'container_iterator<>' will be
    // invoked by the library to evaluate the iterator type to be used
    // for iterating the data elements in the container. We simply return
    // the type of the iterator exposed by the embedded 'std::vector<int>'.
    template <>
    struct container_iterator<client::use_as_container const>
    {
        typedef client::use_as_container::iterator type;
    };

    // The specialization of the templates 'begin_container<>' and
    // 'end_container<>' below will be used by the library to get the iterators
    // pointing to the begin and the end of the data to generate output from.
    //
    // The passed argument refers to the attribute instance passed to the list
    // generator.
    template <>
    struct begin_container<client::use_as_container const>
    {
        static client::use_as_container::iterator
        call(client::use_as_container const& c)
        {
            return client::use_as_container::iterator(&c, &c.value1_);
        }
    };

    template <>
    struct end_container<client::use_as_container const>
    {
        static client::use_as_container::iterator
```

```
        call(client::use_as_container const& c)
        {
            return client::use_as_container::iterator(&c, (int const*)0);
        }
    };
}}}
```

```
// All specializations of attribute customization points have to be placed into
// the namespace boost::spirit::traits.
namespace boost { namespace spirit { namespace traits
{
    // The specialization of the template 'deref_iterator<>' will be used to
    // dereference the iterator associated with our counter data structure.
    template <>
    struct deref_iterator<client::use_as_container::iterator>
    {
        typedef client::use_as_container::type type;

        static type call(client::use_as_container::iterator const& it)
        {
            return *it.current_;
        }
    };

    template <>
    struct next_iterator<client::use_as_container::iterator>
    {
        static void call(client::use_as_container::iterator& it)
        {
            if (it.current_ == &it.container_->value1_)
                it.current_ = &it.container_->value2_;
            else if (it.current_ == &it.container_->value2_)
                it.current_ = &it.container_->value3_;
            else
                it.current_ = 0;
        }
    };

    template <>
    struct compare_iterators<client::use_as_container::iterator>
    {
        static bool call(client::use_as_container::iterator const& it1
          , client::use_as_container::iterator const& it2)
        {
            return it1.current_ == it2.current_ &&
                   it1.container_ == it2.container_;
        }
    };
}}}
```

The last code snippet shows an example using an instance of the data structure `client::use_as_container` to generate output from a List (%) generator:

```
client::use_as_container d2 (1, 2, 3);
// use the instance of a 'client::use_as_container' instead of a STL vector
std::cout << karma::format(karma::int_ % ", ", d2) << std::endl;   // prints: '1, 2, 3'
```

As you can see, the specializations for the customization points as defined above enable the seemless integration of the custom data structure without having to modify the output format or the generator itself.

Dereference the Iterator pointing into a Container Attribute

deref_iterator

The template `deref_iterator` is a type used as an attribute customization point. It is invoked by the *Karma* repetitive generators (such as List (%), Kleene (unary *), Plus (unary +), and Repeat) in order to dereference an iterator pointing to an element of a container holding the attributes to generate output from.

Module Headers

```
#include <boost/spirit/home/support/container.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Iterator, typename Enable>
struct deref_iterator
{
    typedef <unspecified> type;
    static type call(Iterator& it);
};
```

Template parameters

Parameter	Description	Default
`Iterator`	The type, `Iterator` of the iterator to dereference. This is the same as the type returned by the customization point `container_iterator`.	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `deref_iterator` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

`Iterator` An iterator type.

`it` An instance of an iterator, `Iterator`.

`C` A container type a iterator type, `Iterator` belongs to.

Expression Semantics

Expression	Semantics
`deref_iterator<Iterator>::type`	Metafunction result evaluating to the type returned by dereferencing the iterator.
`deref_iterator<Iterator>::call(it)`	Return the element in the container the itertor is referring to. The type of the returned value is the same as returned by the metafunction result `type`.

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types returned by the embedded typedef `type`:

Template Parameters	Value
`Iterator`	The metafunction result `type` evaluates to `boost::detail::iterator_traits<Iterator>::reference` and the function `call()` returns `*it`.
`unused_type const*`	The metafunction result `type` evaluates to `unused_type` and the function `call()` returns `unused`.

When to implement

The customization point `deref_iterator` needs to be implemented for a specific iterator type whenever the container this iterator belongs to is to be used as an attribute in place of a STL container. It is applicable for generators (*Spirit.Karma*) only. As a rule of thumb: it has to be implemented whenever a certain iterator type belongs to a container which is to be passed as an attribute to a generator normally exposing a STL container, `C` and if the container type does not expose the interface of a STL container (i.e. `is_container<C>::type` would normally return `mpl::false_`).

Related Attribute Customization Points

If this customization point is implemented, the following other customization points might need to be implemented as well.

Name	When to implement
`is_container`	Needs to be implemented whenever a type is to be used as a container attribute in *Karma*.
`container_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`begin_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`end_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`deref_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`next_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`compare_iterators`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.

Example

Here are the header files needed to make the example code below compile:

```
#include <boost/spirit/include/karma.hpp>
#include <iostream>
#include <vector>
```

The example (for the full source code please see here: customize_counter.cpp) uses the data structure

```
namespace client
{
    struct counter
    {
        // expose the current value of the counter as our iterator
        typedef int iterator;

        // expose 'int' as the type of each generated element
        typedef int type;

        counter(int max_count)
          : counter_(0), max_count_(max_count)
        {}

        int counter_;
        int max_count_;
    };
}
```

as a direct attribute to the List (%) generator. This type does not expose any of the interfaces of an STL container. It does not even expose the usual semantics of a container. The presented customization points build a counter instance which is incrememnted each time it is accessed. The examples shows how to enable its use as an attribute to *Karma's* repetitive generators.

In order to make this data structure compatible we need to specialize a couple of attribute customization points: `is_container`, `container_iterator`, `begin_container`, and `end_container`. In addition, we specialize one of the iterator related customization points as well: `deref_iterator`.

```
// All specializations of attribute customization points have to be placed into
// the namespace boost::spirit::traits.
//
// Note that all templates below are specialized using the 'const' type.
// This is necessary as all attributes in Karma are 'const'.
namespace boost { namespace spirit { namespace traits
{
    // The specialization of the template 'is_container<>' will tell the
    // library to treat the type 'client::counter' as a container providing
    // the items to generate output from.
    template <>
    struct is_container<client::counter const>
      : mpl::true_
    {};

    // The specialization of the template 'container_iterator<>' will be
    // invoked by the library to evaluate the iterator type to be used
    // for iterating the data elements in the container.
    template <>
    struct container_iterator<client::counter const>
    {
        typedef client::counter::iterator type;
    };

    // The specialization of the templates 'begin_container<>' and
    // 'end_container<>' below will be used by the library to get the iterators
    // pointing to the begin and the end of the data to generate output from.
    // These specializations respectively return the initial and maximum
    // counter values.
    //
    // The passed argument refers to the attribute instance passed to the list
    // generator.
    template <>
    struct begin_container<client::counter const>
    {
        static client::counter::iterator
        call(client::counter const& c)
        {
            return c.counter_;
        }
    };

    template <>
    struct end_container<client::counter const>
    {
        static client::counter::iterator
```

```
        call(client::counter const& c)
        {
            return c.max_count_;
        }
    };
}}}
```

```
// All specializations of attribute customization points have to be placed into
// the namespace boost::spirit::traits.
namespace boost { namespace spirit { namespace traits
{
    // The specialization of the template 'deref_iterator<>' will be used to
    // dereference the iterator associated with our counter data structure.
    // Since we expose the current value as the iterator we just return the
    // current iterator as the return value.
    template <>
    struct deref_iterator<client::counter::iterator>
    {
        typedef client::counter::type type;

        static type call(client::counter::iterator const& it)
        {
            return it;
        }
    };
}}}
```

The last code snippet shows an example using an instance of the data structure `client::counter` to generate output from a List (%) generator:

```
// use the instance of a 'client::counter' instead of a STL vector
client::counter count(4);
std::cout << karma::format(karma::int_ % ", ", count) << std::endl;   // prints: '0, 1, 2, 3'
```

As you can see, the specializations for the customization points as defined above enable the seemless integration of the custom data structure without having to modify the output format or the generator itself.

For other examples of how to use the customization point `deref_iterator` please see here: use_as_container.

Compare two Iterator pointing into a Container Attribute for Equality

compare_iterators

The template `compare_iterators` is a type used as an attribute customization point. It is invoked by the *Karma* repetitive generators (such as List (%), Kleene (unary *), Plus (unary +), and Repeat) in order to compare the current iterator (returned either from `begin_container` or from `next_iterator`) with the end iterator (returned from `end_container`) in order to find the end of the element sequence to gerenate output for.

Module Headers

```
#include <boost/spirit/home/support/container.hpp>
```

Also, see Include Structure.

Note

This header file does not need to be included directly by any user program as it is normally included by other Spirit header files relying on its content.

Namespace

Name
`boost::spirit::traits`

Synopsis

```
template <typename Iterator, typename Enable>
struct compare_iterators
{
    static bool call(Iterator const& it1, Iterator const& it2);
};
```

Template parameters

Parameter	Description	Default
`Iterator`	The type, `Iterator` of the iterator to dereference. This is the same as the type returned by the customization point `container_iterator`.	none
`Enable`	Helper template parameter usable to selectively enable or disable certain specializations of `compare_iterators` utilizing SFINAE (i.e. `boost::enable_if` or `boost::disable_if`).	`void`

Notation

`Iterator`	An iterator type.
`it1`, `it2`	Instance of iterators of type, `Iterator`.
`C`	A container type a iterator type, `Iterator` belongs to.

Expression Semantics

Expression	Semantics
`compare_iterators<Iterator>::call(it1, it2)`	Returns whether the iterators `it1` `it2` are to be treated as beeing equal.

Predefined Specializations

Spirit predefines specializations of this customization point for several types. The following table lists those types together with the types returned by the embedded typedef `type`:

Template Parameters	Value
`Iterator`	The function `call()` returns it1 == it2.
`unused_type const*`	The function `call()` always returns false.

When to implement

The customization point `compare_iterators` needs to be implemented for a specific iterator type whenever the container this iterator belongs to is to be used as an attribute in place of a STL container. It is applicable for generators (*Spirit.Karma*) only. As a rule of thumb: it has to be implemented whenever a certain iterator type belongs to a container which is to be passed as an attribute to a generator normally exposing a STL container, `C` and if the container type does not expose the interface of a STL container (i.e. `is_container<C>::type` would normally return `mpl::false_`).

Related Attribute Customization Points

If this customization point is implemented, the following other customization points might need to be implemented as well.

Name	When to implement
`is_container`	Needs to be implemented whenever a type is to be used as a container attribute in *Karma*.
`container_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`begin_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`end_container`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`deref_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`next_iterator`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.
`compare_iterators`	Karma: List (%), Kleene (unary *), Plus (unary +), Repeat.

Example

For an example of how to use the customization point `compare_iterators` please see here: use_as_container.

Supporting libraries

The multi pass iterator

Backtracking in *Spirit.Qi* requires the use of the following types of iterator: forward, bidirectional, or random access. Because of backtracking, input iterators cannot be used. Therefore, the standard library classes `std::istreambuf_iterator` and `std::istream_iterator`, that fall under the category of input iterators, cannot be used. Another input iterator that is of interest is one that wraps a lexer, such as LEX.

Note

In general, *Spirit.Qi* generates recursive descent parser which require backtracking parsers by design. For this reason we need to provide at least forward iterators to any of *Spirit.Qi*'s API functions. This is not an absolute requirement though. In the future, we shall see more deterministic parsers that require no more than 1 character (token) of lookahead. Such parsers allow us to use input iterators such as the `std::istream_iterator` as is.

Backtracking can be implemented only if we are allowed to save an iterator position, i.e. making a copy of the current iterator. Unfortunately, with an input iterator, there is no way to do so, and thus input iterators will not work with backtracking in *Spirit.Qi*. One solution to this problem is to simply load all the data to be parsed into a container, such as a vector or deque, and then pass the begin and end of the container to *Spirit.Qi*. This method can be too memory intensive for certain applications, which is why the `multi_pass` iterator was created.

Using the multi_pass

The `multi_pass` iterator will convert any input iterator into a forward iterator suitable for use with *Spirit.Qi*. `multi_pass` will buffer data when needed and will discard the buffer when its contents is not needed anymore. This happens either if only one copy of the iterator exists or if no backtracking can occur.

A grammar must be designed with care if the `multi_pass` iterator is used. Any rule that may need to backtrack, such as one that contains an alternative, will cause data to be buffered. The rules that are optimal to use are repetition constructs (as kleene and plus).

Sequences of the form `a >> b` will buffer data as well. This is different from the behaviour of *Spirit.Classic* but for a good reason. Sequences need to reset the current iterator to its initial state if one of the components of a seqeunce fails to match. To compensate for this behaviour we added functionality to the `expect` parsers (i.e. constructs like `a > b`). Expectation points introduce deterministic points into the grammar ensuring no backtracking can occur if they match. For this reason we clear the buffers of any multi_pass iterator on each expectation point, ensuring minimal buffer content even for large grammars.

Important

If you use an error handler in conjunction with the `expect` parser while utilizing a `multi_pass` iterator and you intend to use the error handler to force a `retry` or a `fail` (see the description of error handlers - **FIXME**: insert link), then you need to instantiate the error handler using `retry` or `fail`, for instance:

```
rule r<iterator_type> r;
on_error<retry>(r, std::cout << phoenix::val("Error!"));
```

If you fail to do so the resulting code will trigger an assert statement at runtime.

Any rule that repeats, such as kleene_star (`*a`) or positive such as (`+a`), will only buffer the data for the current repetition.

In typical grammars, ambiguity and therefore lookahead is often localized. In fact, many well designed languages are fully deterministic and require no lookahead at all. Peeking at the first character from the input will immediately determine the alternative branch to take. Yet, even with highly ambiguous grammars, alternatives are often of the form `*(a | b | c | d)`. The input iterator moves on and is never stuck at the beginning. Let's look at a Pascal snippet for example:

```
program =
        programHeading >> block >> '.'
    ;

block =
       *(   labelDeclarationPart
        |   constantDefinitionPart
        |   typeDefinitionPart
        |   variableDeclarationPart
        |   procedureAndFunctionDeclarationPart
        )
    >>  statementPart
    ;
```

Notice the alternatives inside the Kleene star in the rule block . The rule gobbles the input in a linear manner and throws away the past history with each iteration. As this is fully deterministic LL(1) grammar, each failed alternative only has to peek 1 character (token). The alternative that consumes more than 1 character (token) is definitely a winner. After which, the Kleene star moves on to the next.

Now, after the lecture on the features to be careful with when using `multi_pass`, you may think that `multi_pass` is way too restrictive to use. That's not the case. If your grammar is deterministic, you can make use of the `flush_multi_pass` pseudo parser in your grammar to ensure that data is not buffered when unnecessary (`flush_multi_pass` is available from the *Spirit.Qi* parser Repository).

Here we present a minimal example showing a minimal use case. The `multi_pass` iterator is highly configurable, but the default policies have been chosen so that its easily usable with input iterators such as `std::istreambuf_iterator`. For the complete source code of this example please refer to multi_pass.cpp.

```
int main()
{
    namespace spirit = boost::spirit;
    using spirit::ascii::space;
    using spirit::ascii::char_;
    using spirit::qi::double_;
    using spirit::qi::eol;

    std::ifstream in("multi_pass.txt");    // we get our input from this file
    if (!in.is_open()) {
        std::cout << "Could not open input file: 'multi_pass.txt'" << std::endl;
        return -1;
    }

    typedef std::istreambuf_iterator<char> base_iterator_type;
    spirit::multi_pass<base_iterator_type> first =
        spirit::make_default_multi_pass(base_iterator_type(in));

    std::vector<double> v;
    bool result = spirit::qi::phrase_parse(first
      , spirit::make_default_multi_pass(base_iterator_type())
      , double_ >> *(',' >> double_)              // recognize list of doubles
      , space | '#' >> *(char_ - eol) >> eol      // comment skipper
      , v);                                       // data read from file

    if (!result) {
        std::cout << "Failed parsing input file!" << std::endl;
        return -2;
    }

    std::cout << "Successfully parsed input file!" << std::endl;
    return 0;
}
```

Using the flush_multi_pass parser

The Spirit Repository contains the `flush_multi_pass` parser component. This is usable in conjunction with the `multi_pass` iterator to minimize the buffering. It allows to insert explicit synchronization points into your grammar where it is safe to clear any stored input as it is ensured that no backtracking can occur at this point anymore.

When the `flush_multi_pass` parser is used with `multi_pass`, it will call `multi_pass::clear_queue()`. This will cause any buffered data to be erased. This also will invalidate all other copies of multi_pass and they should not be used. If they are, an `boost::illegal_backtracking` exception will be thrown.

The multi_pass Policies

The `multi_pass` iterator is a templated class configurable using policies. The description of `multi_pass` above is how it was originally implemented (before it used policies), and is the default configuration now. But, `multi_pass` is capable of much more. Because of the open-ended nature of policies, you can write your own policy to make `multi_pass` behave in a way that we never before imagined.

The multi_pass class has two template parameters:

The multi_pass template parameters

Input — The type multi_pass uses to acquire it's input. This is typically an input iterator, or functor.

Policies — The combined policies to use to create an instance of a multi_pass iterator. This combined policy type is described below

It is possible to implement all of the required functionality of the combinded policy in a single class. But it has shown to be more convenient to split this into four different groups of functions, i.e. four separate, but well coordinated policies. For this reason the `multi_pass` library implements a template `iterator_policies::default_policy` allowing to combine several different policies, each implementing one of the functionality groups:

Table 12. Policies needed for default_policy template

Template Parameter	Description
`OwnershipPolicy`	This policy determines how `multi_pass` deals with it's shared components.
`CheckingPolicy`	This policy determines how checking for invalid iterators is done.
`InputPolicy`	A class that defines how `multi_pass` acquires its input. The `InputPolicy` is parameterized by the `Input` template parameter to the `multi_pass`.
`StoragePolicy`	The buffering scheme used by `multi_pass` is determined and managed by the StoragePolicy.

The `multi_pass` library contains several predefined policy implementations for each of the policy types as described above. First we will describe those predefined types. Afterwards we will give some guidelines how you can write your own policy implementations.

Predefined policies

All predefined `multi_pass` policies are defined in the namespace `boost::spirit::iterator_policies`.

Table 13. Predefined policy classes

Class name	Description
InputPolicy classes	
`input_iterator`	This policy directs `multi_pass` to read from an input iterator of type `Input`.
`lex_input`	This policy obtains it's input by calling yylex(), which would typically be provided by a scanner generated by Flex. If you use this policy your code must link against a Flex generated scanner.
`functor_input`	This input policy obtains it's data by calling a functor of type `Input`. The functor must meet certain requirements. It must have a typedef called `result_type` which should be the type returned from `operator()`. Also, since an input policy needs a way to determine when the end of input has been reached, the functor must contain a static variable named `eof` which is comparable to a variable of `result_type`.
`split_functor_input`	This is essentially the same as the `functor_input` policy except that the (user supplied) funtion object exposes separate `unique` and `shared` sub classes, allowing to integrate the functors *unique* data members with the `multi_pass` data items held by each instance and its *shared* data members will be integrated with the `multi_pass` members shared by all copies.
OwnershipPolicy classes	
`ref_counted`	This class uses a reference counting scheme. The `multi_pass` will delete it's shared components when the count reaches zero.
`first_owner`	When this policy is used, the first `multi_pass` created will be the one that deletes the shared data. Each copy will not take ownership of the shared data. This works well for Spirit, since no dynamic allocation of iterators is done. All copies are made on the stack, so the original iterator has the longest lifespan.
CheckingPolicy classes	
`no_check`	This policy does no checking at all.
`buf_id_check`	This policy keeps around a buffer id, or a buffer age. Every time `clear_queue()` is called on a `multi_pass` iterator, it is possible that all other iterators become invalid. When `clear_queue()` is called, `buf_id_check` increments the buffer id. When an iterator is dereferenced, this policy checks that the buffer id of the iterator matches the shared buffer id. This policy is most effective when used together with the `split_std_deque` StoragePolicy. It should not be used with the `fixed_size_queue` StoragePolicy, because it will not detect iterator dereferences that are out of range.

Class name	Description
full_check	This policy has not been implemented yet. When it is, it will keep track of all iterators and make sure that they are all valid. This will be mostly useful for debugging purposes as it will incur significant overhead.
StoragePolicy classes	
`split_std_deque`	Despite its name this policy keeps all buffered data in a `std::vector`. All data is stored as long as there is more than one iterator. Once the iterator count goes down to one, and the queue is no longer needed, it is cleared, freeing up memory. The queue can also be forcibly cleared by calling `multi_pass::clear_queue()`.
`fixed_size_queue<N>`	This policy keeps a circular buffer that is size `N+1` and stores `N` elements. `fixed_size_queue` is a template with a `std::size_t` parameter that specified the queue size. It is your responsibility to ensure that `N` is big enough for your parser. Whenever the foremost iterator is incremented, the last character of the buffer is automatically erased. Currently there is no way to tell if an iterator is trailing too far behind and has become invalid. No dynamic allocation is done by this policy during normal iterator operation, only on initial construction. The memory usage of this `StoragePolicy` is set at `N+1` bytes, unlike `split_std_deque`, which is unbounded.

Combinations: How to specify your own custom multi_pass

The beauty of policy based designs is that you can mix and match policies to create your own custom iterator by selecting the policies you want. Here's an example of how to specify a custom `multi_pass` that wraps an `std::istream_iterator<char>`, and is slightly more efficient than the default `multi_pass` (as generated by the `make_default_multi_pass()` API function) because it uses the `iterator_policies::first_owner` OwnershipPolicy and the `iterator_policies::no_check` CheckingPolicy:

```
typedef multi_pass<
    std::istream_iterator<char>
  , iterator_policies::default_policy<
        iterator_policies::first_owner
      , iterator_policies::no_check
      , iterator_policies::input_iterator
      , iterator_policies::split_std_deque
    >
> first_owner_multi_pass_type;
```

The default template parameters for `iterator_policies::default_policy` are:

- `iterator_policies::ref_counted` OwnershipPolicy
- `iterator_policies::no_check` CheckingPolicy, if `BOOST_SPIRIT_DEBUG` is defined: `iterator_policies::buf_id_check` CheckingPolicy
- `iterator_policies::input_iterator` InputPolicy, and
- `iterator_policies::split_std_deque` StoragePolicy.

So if you use `multi_pass<std::istream_iterator<char> >` you will get those pre-defined behaviors while wrapping an `std::istream_iterator<char>`.

Dealing with constant look ahead

There is one other pre-defined class called `look_ahead`. The class `look_ahead` is another predefine `multi_pass` iterator type. It has two template parameters: `Input`, the type of the input iterator to wrap, and a `std::size_t N`, which specifies the size of the buffer to the `fixed_size_queue` policy. While the default multi_pass configuration is designed for safey, `look_ahead` is designed for speed. `look_ahead` is derived from a multi_pass with the following policies: `input_iterator` InputPolicy, `first_owner` OwnershipPolicy, `no_check` CheckingPolicy, and `fixed_size_queue<N>` StoragePolicy.

How to write a functor for use with the `functor_input` InputPolicy

If you want to use the `functor_input` InputPolicy, you can write your own function object that will supply the input to `multi_pass`. The function object must satisfy several requirements. It must have a typedef `result_type` which specifies the return type of its `operator()`. This is standard practice in the STL. Also, it must supply a static variable called eof which is compared against to know whether the input has reached the end. Last but not least the function object must be default constructible. Here is an example:

```
// define the function object
class iterate_a2m
{
public:
    typedef char result_type;

    iterate_a2m() : c('A') {}
    iterate_a2m(char c) : c_(c) {}

    result_type operator()() const
    {
        if (c_ == 'M')
            return eof;
        return c_++;
    }

    static result_type eof;

private:
    char c_;
};

iterate_a2m::result_type iterate_a2m::eof = iterate_a2m::result_type('\0');

// create two iterators using the define function object, one of which is
// an end iterator
typedef multi_pass<my_functor
  , iterator_policies::functor_input
  , iterator_policies::first_owner
  , iterator_policies::no_check
  , iterator_policies::split_std_deque>
functor_multi_pass_type;

functor_multi_pass_type first = functor_multi_pass_t(my_functor());
functor_multi_pass_type last;

// use the iterators: this will print "ABCDEFGHIJKL"
while (first != last) {
    std::cout << *first;
    ++first;
}
```

How to write policies for use with multi_pass

All policies to be used with the `default_policy` template need to have two embedded classes: `unique` and `shared`. The `unique` class needs to implement all required functions for a particular policy type. In addition it may hold all member data items being

unique for a particular instance of a `multi_pass` (hence the name). The `shared` class does not expose any member functions (except sometimes a constructor), but it may hold all member data items to be *shared* between all copies of a particular `multi_pass`.

InputPolicy

An `InputPolicy` must have the following interface:

```
struct input_policy
{
    // Input is the same type used as the first template parameter
    // while instantiating the multi_pass
    template <typename Input>
    struct unique
    {
        // these typedef's will be exposed as the multi_pass iterator
        // properties
        typedef __unspecified_type__ value_type;
        typedef __unspecified_type__ difference_type;
        typedef __unspecified_type__ distance_type;
        typedef __unspecified_type__ pointer;
        typedef __unspecified_type__ reference;

        unique() {}
        explicit unique(Input) {}

        // destroy is called whenever the last copy of a multi_pass is
        // destructed (ownership_policy::release() returned true)
        //
        //   mp:    is a reference to the whole multi_pass instance
        template <typename MultiPass>
        static void destroy(MultiPass& mp);

        // swap is called by multi_pass::swap()
        void swap(unique&);

        // advance_input is called whenever the next input character/token
        // should be fetched.
        //
        //   mp:    is a reference to the whole multi_pass instance
        //   t:     is a reference where the next character/token should be
        //          stored
        //
        // This method is expected to return the parameter t
        template <typename MultiPass>
        static value_type& advance_input(MultiPass& mp, value_type& t);

        // input_at_eof is called to test whether this instance is a
        // end of input iterator.
        //
        //   mp:    is a reference to the whole multi_pass instance
        //   t:     is the current token
        //
        // This method is expected to return true if the end of input is
        // reached. It is often used in the implementation of the function
        // storage_policy::is_eof.
        template <typename MultiPass>
        static bool input_at_eof(MultiPass const& mp, value_type const& t);

        // input_is_valid is called to verify if the parameter t represents
        // a valid input character/token
        //
        //   mp:    is a reference to the whole multi_pass instance
        //   t:     is the character/token to test for validity
```

```
        //
        // This method is expected to return true if the parameter t
        // represents a valid character/token.
        template <typename MultiPass>
        static bool input_is_valid(MultiPass const& mp, value_type const& t);
    };

    // Input is the same type used as the first template parameter
    // while instantiating the multi_pass
    template <typename Input>
    struct shared
    {
        explicit shared(Input) {}
    };
};
```

It is possible to derive the struct `unique` from the type `boost::spirit::detail::default_input_policy`. This type implements a minimal sufficient interface for some of the required functions, simplifying the task of writing a new input policy.

This class may implement a function `destroy()` being called during destruction of the last copy of a `multi_pass`. This function should be used to free any of the shared data items the policy might have allocated during construction of its `shared` part. Because of the way `multi_pass` is implemented any allocated data members in `shared` should not be deep copied in a copy constructor of `shared`.

OwnershipPolicy

The `OwnershipPolicy` must have the following interface:

```
struct ownership_policy
{
    struct unique
    {
        // destroy is called whenever the last copy of a multi_pass is
        // destructed (ownership_policy::release() returned true)
        //
        //   mp:    is a reference to the whole multi_pass instance
        template <typename MultiPass>
        static void destroy(MultiPass& mp);

        // swap is called by multi_pass::swap()
        void swap(unique&);

        // clone is called whenever a multi_pass is copied
        //
        //   mp:    is a reference to the whole multi_pass instance
        template <typename MultiPass>
        static void clone(MultiPass& mp);

        // release is called whenever a multi_pass is destroyed
        //
        //   mp:    is a reference to the whole multi_pass instance
        //
        // The method is expected to return true if the destructed
        // instance is the last copy of a particular multi_pass.
        template <typename MultiPass>
        static bool release(MultiPass& mp);

        // is_unique is called to test whether this instance is the only
        // existing copy of a particular multi_pass
        //
        //   mp:    is a reference to the whole multi_pass instance
        //
        // The method is expected to return true if this instance is unique
        // (no other copies of this multi_pass exist).
        template <typename MultiPass>
        static bool is_unique(MultiPass const& mp);
    };

    struct shared {};
};
```

It is possible to derive the struct `unique` from the type `boost::spirit::detail::default_ownership_policy`. This type implements a minimal sufficient interface for some of the required functions, simplifying the task of writing a new ownership policy.

This class may implement a function `destroy()` being called during destruction of the last copy of a `multi_pass`. This function should be used to free any of the shared data items the policy might have allocated during construction of its `shared` part. Because of the way `multi_pass` is implemented any allocated data members in `shared` should not be deep copied in a copy constructor of `shared`.

CheckingPolicy

The `CheckingPolicy` must have the following interface:

```
struct checking_policy
{
    struct unique
    {
        // swap is called by multi_pass::swap()
        void swap(unique&);

        // destroy is called whenever the last copy of a multi_pass is
        // destructed (ownership_policy::release() returned true)
        //
        //   mp:    is a reference to the whole multi_pass instance
        template <typename MultiPass>
        static void destroy(MultiPass& mp);

        // check is called before the multi_pass is dereferenced or
        // incremented.
        //
        //   mp:    is a reference to the whole multi_pass instance
        //
        // This method is expected to make sure the multi_pass instance is
        // still valid. If it is invalid an exception should be thrown.
        template <typename MultiPass>
        static void check(MultiPass const& mp);

        // clear_queue is called whenever the function
        // multi_pass::clear_queue is called on this instance
        //
        //   mp:    is a reference to the whole multi_pass instance
        template <typename MultiPass>
        static void clear_queue(MultiPass& mp);
    };

    struct shared {};
};
```

It is possible to derive the struct `unique` from the type `boost::spirit::detail::default_checking_policy`. This type implements a minimal sufficient interface for some of the required functions, simplifying the task of writing a new checking policy.

This class may implement a function `destroy()` being called during destruction of the last copy of a `multi_pass`. This function should be used to free any of the shared data items the policy might have allocated during construction of its `shared` part. Because of the way `multi_pass` is implemented any allocated data members in `shared` should not be deep copied in a copy constructor of `shared`.

StoragePolicy

A `StoragePolicy` must have the following interface:

```
struct storage_policy
{
    // Value is the same type as typename MultiPass::value_type
    template <typename Value>
    struct unique
    {
        // destroy is called whenever the last copy of a multi_pass is
        // destructed (ownership_policy::release() returned true)
        //
        //   mp:    is a reference to the whole multi_pass instance
        template <typename MultiPass>
        static void destroy(MultiPass& mp);

        // swap is called by multi_pass::swap()
        void swap(unique&);

        // dereference is called whenever multi_pass::operator*() is invoked
        //
        //   mp:    is a reference to the whole multi_pass instance
        //
        // This function is expected to return a reference to the current
        // character/token.
        template <typename MultiPass>
        static typename MultiPass::reference dereference(MultiPass const& mp);

        // increment is called whenever multi_pass::operator++ is invoked
        //
        //   mp:    is a reference to the whole multi_pass instance
        template <typename MultiPass>
        static void increment(MultiPass& mp);

        //
        //   mp:    is a reference to the whole multi_pass instance
        template <typename MultiPass>
        static void clear_queue(MultiPass& mp);

        // is_eof is called to test whether this instance is a end of input
        // iterator.
        //
        //   mp:    is a reference to the whole multi_pass instance
        //
        // This method is expected to return true if the end of input is
        // reached.
        template <typename MultiPass>
        static bool is_eof(MultiPass const& mp);

        // less_than is called whenever multi_pass::operator==() is invoked
        //
        //   mp:    is a reference to the whole multi_pass instance
        //   rhs:   is the multi_pass reference this instance is compared
        //          to
        //
        // This function is expected to return true if the current instance
        // is eual to the right hand side multi_pass instance
        template <typename MultiPass>
        static bool equal_to(MultiPass const& mp, MultiPass const& rhs);

        // less_than is called whenever multi_pass::operator<() is invoked
        //
        //   mp:    is a reference to the whole multi_pass instance
        //   rhs:   is the multi_pass reference this instance is compared
        //          to
        //
```

```
        // This function is expected to return true if the current instance
        // is less than the right hand side multi_pass instance
        template <typename MultiPass>
        static bool less_than(MultiPass const& mp, MultiPass const& rhs);
    };

    // Value is the same type as typename MultiPass::value_type
    template <typename Value>
    struct shared {};
};
```

It is possible to derive the struct `unique` from the type `boost::spirit::detail::default_storage_policy`. This type implements a minimal sufficient interface for some of the required functions, simplifying the task of writing a new storage policy.

This class may implement a function `destroy()` being called during destruction of the last copy of a `multi_pass`. This function should be used to free any of the shared data items the policy might have allocated during construction of its `shared` part. Because of the way `multi_pass` is implemented any allocated data members in `shared` should not be deep copied in a copy constructor of `shared`.

Generally, a `StoragePolicy` is the trickiest policy to implement. You should study and understand the existing `StoragePolicy` classes before you try and write your own.

Spirit FAQ

I'm getting multiple symbol definition errors while using Visual C++. Anything I could do about that?

Do you see strange multiple symbol definition linker errors mentioning `boost::mpl::failed` and `boost::spirit::qi::rule`? Then this FAQ entry might be for you.

Boost.Mpl implements a macro `BOOST_MPL_ASSERT_MSG()` which essentially is a more powerfull version of static_assert. Unfortunately under certain circumstances using this macro may lead to the aformentioned linker errors.

Spirit allows you to define a preprocessor constant disabling the usage of `BOOST_MPL_ASSERT_MSG()`, while switching to `BOOST_STATIC_ASSERT()` instead. For that you need define BOOST_SPIRIT_DONT_USE_MPL_ASSERT_MSG=1. Do this by adding

```
-DBOOST_SPIRIT_DONT_USE_MPL_ASSERT_MSG=1
```

on the compiler command line or by inserting a

```
#define BOOST_SPIRIT_DONT_USE_MPL_ASSERT_MSG 1
```

into your code before any Spirit headers get included.

Using this trick has no adverse effects on any of the functionality of Spirit. The only change you might see while using this workaround is less verbose error messages generated from static_assert.

I'm very confused about the header hell in my boost/spirit directory. What's all this about?

The boost/spirit directory currently holds two versions of the Spirit library: *Spirit.Classic* (former V1.8.x) and SpiritV2. Both are completely independent and usually not used at the same time. Do not mix these two in the same grammar.

Spirit.Classic evolved over years in a fairly complex directory structure:

```
boost/spirit/actor
boost/spirit/attribute
boost/spirit/core
boost/spirit/debug
boost/spirit/dynamic
boost/spirit/error_handling
boost/spirit/iterator
boost/spirit/meta
boost/spirit/symbols
boost/spirit/tree
boost/spirit/utility
```

While introducing Spirit V2 we restructured the directory structure in order to accommodate two versions at the same time. All of *Spirit.Classic* now lives in the directory

```
boost/spirit/home/classic
```

where the directories above contain forwarding headers to the new location allowing to maintain application compatibility. The forwarding headers issue a warning (starting with Boost V1.38) telling the user to change their include paths. Please expect the above directories/forwarding headers to go away soon.

This explains the need for the directory

```
boost/spirit/include
```

which contains forwarding headers as well. But this time the headers won't go away. We encourage application writers to use only the includes contained in this directory. This allows us to restructure the directories underneath if needed without worrying application compatibility. Please use those files in your application only. If it turns out that some forwarding file is missing, please report this as a bug.

Spirit V2 is not about parsing only anymore (as *Spirit.Classic*). It now consists out of 3 parts (sub-libraries): *Spirit.Qi*, *Spirit.Karma*, and *Spirit.Lex*. The header files for those live in

```
boost/spirit/home/qi
boost/spirit/home/karma
boost/spirit/home/lex
```

and have forwarding headers in

```
boost/spirit/include
```

Spirit.Qi is the direct successor to *Spirit.Classic* as it implements a DSEL (domain specific embedded language) allowing to write parsers using the syntax of C++ itself (parsers in the sense turning a sequence of bytes into an internal data structure). It is not compatible with *Spirit.Classic*, the main concepts are similar, though.

Spirit.Karma is the counterpart to *Spirit.Qi*. It implements a similar DSEL but for writing generators (i.e. the things turning internal data structures into a sequence of bytes, most of the time - strings). *Spirit.Karma* is the Yang to *Spirit.Qi*'s Yin, it's almost like a mirrored picture.

Spirit.Lex is (as the name implies) a library allowing to write lexical analyzers. These are either usable standalone or can be used as a frontend for *Spirit.Qi* parsers. If you know flex you shouldn't have problems understanding *Spirit.Lex*. This library actually doesn't implement the lexer itself. All it does is to provide an interface to pre-existing lexical analyzers. Currently it's using Ben Hansons excellent Lexertl library (proposed for a Boost review, BTW) as its underlying workhorse.

Again, don't use any of the header files underneath the boost/spirit/home directory directly, always include files from the boost/spirit/include directory.

The last bit missing is Boost.Phoenix (which currently still lives under the Spirit umbrella, but already has been accepted as a Boost library, so it will move away). Boost.Phoenix is a library allowing to write functional style C++, which is interesting in itself, but as it initially has been developed for Spirit, it is nicely integrated and very useful when it comes to writing semantic actions. I think using the boost/spirit/include/phoenix_... headers will be safe in the future as well, as we will probably redirect to the Boost.Phoenix headers as soon as these are available.

Why doesn't my symbol table work in a `no_case` directive?

In order to perform case-insensitive parsing (using `no_case`) with a symbol table (i.e. use a `symbols<Ch, T>` parser in a `no_case` directive), that symbol table needs to be filled with all-lowercase contents. Entries containing one or more uppercase characters will not match any input.

I'm getting a compilation error mentioning `boost::function` and/or `boost::function4`. What does this mean?

If you are using Visual C++ and have an error like:

```
error C2664: 'bool boost::function4<R,T0,T1,T2,T3>::operator ()(T0,T1,T2,T3) const' :
    cannot convert parameter 4 from '...' to '...'
```

or you are using GCC and have an error like:

```
error: no match for call to '(const boost::function<bool ()(...)>) (...)'
note: candidates are: ... boost::function4<R,T1,T2,T3,T4>::operator()(T0,T1,T2,T3) const [with ...]
```

then this FAQ entry may help you.

The definition of a Rule or Grammar may contain a skip parser type. If it does, it means that non-terminal can only be used with a skip parser of a compatible type. The error above arises when this is not the case, i.e.:

- a non-terminal defined with a skip parser type is used without a skip parser; for example, a rule with a skip parser type is used inside a `lexeme` directive, or a grammar with a skip parser type is used in `parse` instead of `phrase_parse`,
- or a non-terminal is used with a skip parser of an incompatible type; for example, a rule defined with one skip parser type calls a second rule defined with another, incompatible skip parser type.

Note

The same applies to *Spirit.Karma*, replacing 'skip parser' and `lexeme` by 'delimit generator' and `verbatim`. Similarily, corresponding error messages in *Spirit.Karma* reference `boost::function3` and the 3rd parameter (instead of the 4th).

Notes

Porting from Spirit 1.8.x

The current version of Spirit is a complete rewrite of earlier versions (we refer to earlier versions as *Spirit.Classic*). The parser generators are now only one part of the whole library. The parser submodule of Spirit is now called *Spirit.Qi*. It is conceptually different and exposes a completely different interface. Generally, there is no easy (or automated) way of converting parsers written for *Spirit.Classic* to *Spirit.Qi*. Therefore this section can give only guidelines on how to approach porting your older parsers to the current version of Spirit.

Include Files

The overall directory structure of the Spirit directories is described in the section Include Structure and the FAQ entry Header Hell. This should give you a good overview on how to find the needed header files for your new parsers. Moreover, each section in the Qi Reference lists the required include files needed for any particular component.

It is possible to tell from the name of a header file, what version it belongs to. While all main include files for *Spirit.Classic* have the string 'classic_' in their name, for instance:

```
#include <boost/spirit/include/classic_core.hpp>
```

we named all main include files for *Spirit.Qi* to have the string 'qi_' as part of their name, for instance:

```
#include <boost/spirit/include/qi_core.hpp>
```

The following table gives a rough list of corresponding header file between *Spirit.Classic* and *Spirit.Qi*, but this can be used as a starting point only, as several components have either been moved to different submodules or might not exist in the never version anymore. We list only include files for the topmost submodules. For header files required for more lower level components please refer to the corresponding reference documentation of this component.

Include file in *Spirit.Classic*	**Include file in *Spirit.Qi***
`classic.hpp`	`qi.hpp`
`classic_actor.hpp`	none, use Boost.Phoenix for writing semantic actions
`classic_attribute.hpp`	none, use local variables for rules instead of closures, the primitives parsers now directly support lazy parametrization
`classic_core.hpp`	`qi_core.hpp`
`classic_debug.hpp`	`qi_debug.hpp`
`classic_dynamic.hpp`	none, use *Spirit.Qi* predicates instead of if_p, while_p, for_p (included by `qi_core.hpp`), the equivalent for lazy_p is now included by `qi_auxiliary.hpp`
`classic_error_handling.hpp`	none, included in `qi_core.hpp`
`classic_meta.hpp`	none
`classic_symbols.hpp`	none, included in `qi_core.hpp`
`classic_utility.hpp`	none, not part of *Spirit.Qi* anymore, these components will be added over time to the Repository

The Free Parse Functions

The free parse functions (i.e. the main parser API) has been changed. This includes the names of the free functions as well as their interface. In *Spirit.Classic* all free functions were named `parse`. In *Spirit.Qi* they are are named either `qi::parse` or `qi::phrase_parse` depending on whether the parsing should be done using a skipper (`qi::phrase_parse`) or not (`qi::parse`). All free functions now return a simple `bool`. A returned `true` means success (i.e. the parser has matched) or `false` (i.e. the parser didn't match). This is equivalent to the former old `parse_info` member `hit`. *Spirit.Qi* doesn't support tracking of the matched input length anymore. The old `parse_info` member `full` can be emulated by comparing the iterators after `qi::parse` returned.

All code examples in this section assume the following include statements and using directives to be inserted. For *Spirit.Classic*:

```
#include <boost/spirit/include/classic.hpp>
#include <boost/spirit/include/phoenix1.hpp>
#include <iostream>
#include <string>
```

```
using namespace boost::spirit::classic;
```

and for *Spirit.Qi*:

```
#include <boost/spirit/include/qi.hpp>
#include <boost/spirit/include/phoenix_operator.hpp>
#include <iostream>
#include <string>
#include <algorithm>
```

```
using namespace boost::spirit;
```

The following similar examples should clearify the differences. First the base example in *Spirit.Classic*:

```
std::string input("1,1");
parse_info<std::string::iterator> pi = parse(input.begin(), input.end(), int_p);

if (pi.hit)
    std::cout << "successful match!\n";

if (pi.full)
    std::cout << "full match!\n";
else
    std::cout << "stopped at: " << std::string(pi.stop, input.end()) << "\n";

std::cout << "matched length: " << pi.length << "\n";
```

And here is the equivalent piece of code using *Spirit.Qi*:

```
std::string input("1,1");
std::string::iterator it = input.begin();
bool result = qi::parse(it, input.end(), qi::int_);

if (result)
    std::cout << "successful match!\n";

if (it == input.end())
    std::cout << "full match!\n";
else
    std::cout << "stopped at: " << std::string(it, input.end()) << "\n";

// seldomly needed: use std::distance to calculate the length of the match
std::cout << "matched length: " << std::distance(input.begin(), it) << "\n";
```

The changes required for phrase parsing (i.e. parsing using a skipper) are similar. Here is how phrase parsing works in *Spirit.Classic*:

```
std::string input(" 1, 1");
parse_info<std::string::iterator> pi = parse(input.begin(), input.end(), int_p, space_p);

if (pi.hit)
    std::cout << "successful match!\n";

if (pi.full)
    std::cout << "full match!\n";
else
    std::cout << "stopped at: " << std::string(pi.stop, input.end()) << "\n";

std::cout << "matched length: " << pi.length << "\n";
```

And here the equivalent example in *Spirit.Qi*:

```
std::string input(" 1, 1");
std::string::iterator it = input.begin();
bool result = qi::phrase_parse(it, input.end(), qi::int_, ascii::space);

if (result)
    std::cout << "successful match!\n";

if (it == input.end())
    std::cout << "full match!\n";
else
    std::cout << "stopped at: " << std::string(it, input.end()) << "\n";

// seldomly needed: use std::distance to calculate the length of the match
std::cout << "matched length: " << std::distance(input.begin(), it) << "\n";
```

Note, how character parsers are in a separate namespace (here `boost::spirit::ascii::space`) as *Spirit.Qi* now supports working with different character sets. See the section Character Encoding Namespace for more information.

Naming Conventions

In *Spirit.Classic* all parser primitives have suffixes appended to their names, encoding their type: `"_p"` for parsers, `"_a"` for lazy actions, `"_d"` for directives, etc. In *Spirit.Qi* we don't have anything similar. The only suffixes are single underscore letters `"_"` applied where the name would otherwise conflict with a keyword or predefined name (such as `int_` for the integer parser). Overall, most, if not all primitive parsers and directives have been renamed. Please see the Qi Quick Reference for an overview on the names for the different available parser primitives, directives and operators.

Parser Attributes

In *Spirit.Classic* most of the parser primitives don't expose a specific attribute type. Most parsers expose the pair of iterators pointing to the matched input sequence. As in *Spirit.Qi* all parsers expose a parser specific attribute type it introduces a special directive `raw[]` allowing to achieve a similar effect as in *Spirit.Classic*. The `raw[]` directive exposes the pair of iterators pointing to the matching sequence of its embedded parser. Even if we very much encourage you to rewrite your parsers to take advantage of the generated parser specific attributes, sometimes it is helpful to get access to the underlying matched input sequence.

Grammars and Rules

The `grammar<>` and `rule<>` types are of equal importance to *Spirit.Qi* as they are for *Spirit.Classic*. Their main purpose is still the same: they allow to define non-terminals and they are the main building blocks for more complex parsers. Nevertheless, both types have been redesigned and their interfaces have changed. Let's have a look at two examples first, we'll explain the differences afterwards. Here is a simple grammar and its usage in *Spirit.Classic*:

```
struct roman : public grammar<roman>
{
    template <typename ScannerT>
    struct definition
    {
        definition(roman const& self)
        {
            hundreds.add
                ("C"  , 100)("CC"  , 200)("CCC"  , 300)("CD" , 400)("D" , 500)
                ("DC" , 600)("DCC" , 700)("DCCC" , 800)("CM" , 900) ;

            tens.add
                ("X"  , 10)("XX"  , 20)("XXX"  , 30)("XL" , 40)("L" , 50)
                ("LX" , 60)("LXX" , 70)("LXXX" , 80)("XC" , 90) ;

            ones.add
                ("I"  , 1)("II"  , 2)("III"  , 3)("IV" , 4)("V" , 5)
                ("VI" , 6)("VII" , 7)("VIII" , 8)("IX" , 9) ;

            first = eps_p         [phoenix::var(self.r) = phoenix::val(0)]
                >>  (  +ch_p('M') [phoenix::var(self.r) += phoenix::val(1000)]
                    ||  hundreds  [phoenix::var(self.r) += phoenix::_1]
                    ||  tens      [phoenix::var(self.r) += phoenix::_1]
                    ||  ones      [phoenix::var(self.r) += phoenix::_1]
                    ) ;
        }

        rule<ScannerT> first;
        symbols<unsigned> hundreds;
        symbols<unsigned> tens;
        symbols<unsigned> ones;

        rule<ScannerT> const& start() const { return first; }
    };

    roman(unsigned& r_) : r(r_) {}
    unsigned& r;
};
```

```
std::string input("MMIX");        // MMIX == 2009
unsigned value = 0;
roman r(value);
parse_info<std::string::iterator> pi = parse(input.begin(), input.end(), r);
if (pi.hit)
    std::cout << "successfully matched: " << value << "\n";
```

And here is a similar grammar and its usage in *Spirit.Qi*:

```
template <typename Iterator>
struct roman : qi::grammar<Iterator, unsigned()>
{
    roman() : roman::base_type(first)
    {
        hundreds.add
            ("C"  , 100)("CC"  , 200)("CCC"  , 300)("CD" , 400)("D" , 500)
            ("DC" , 600)("DCC" , 700)("DCCC" , 800)("CM" , 900) ;

        tens.add
            ("X"  , 10)("XX"  , 20)("XXX"  , 30)("XL" , 40)("L" , 50)
            ("LX" , 60)("LXX" , 70)("LXXX" , 80)("XC" , 90) ;

        ones.add
            ("I"  , 1)("II"  , 2)("III"  , 3)("IV" , 4)("V" , 5)
            ("VI" , 6)("VII" , 7)("VIII" , 8)("IX" , 9) ;

        // qi::_val refers to the attribute of the rule on the left hand side
        first = eps          [qi::_val = 0]
            >>  (  +lit('M') [qi::_val += 1000]
                ||  hundreds [qi::_val += qi::_1]
                ||  tens     [qi::_val += qi::_1]
                ||  ones     [qi::_val += qi::_1]
                ) ;
    }

    qi::rule<Iterator, unsigned()> first;
    qi::symbols<char, unsigned> hundreds;
    qi::symbols<char, unsigned> tens;
    qi::symbols<char, unsigned> ones;
};
```

```
std::string input("MMIX");        // MMIX == 2009
std::string::iterator it = input.begin();
unsigned value = 0;
roman<std::string::iterator> r;
if (qi::parse(it, input.end(), r, value))
    std::cout << "successfully matched: " << value << "\n";
```

Both versions look similarily enough, but we see several differences (we will cover each of those differences in more detail below):

- Neither the grammars nor the rules depend on a scanner type anymore, both depend only on the underlying iterator type. That means the dreaded scanner business is no issue anymore!
- Grammars have no embedded class `definition` anymore
- Grammars and rules may have an explicit attribute type specified in their definition
- Grammars do not have any explicit start rules anymore. Instead one of the contained rules is used as a start rule by default.

The first two points are tightly interrelated. The scanner business (see the FAQ number one of *Spirit.Classic* here: The Scanner Business) has been a problem for a long time. The grammar and rule types have been specifically redesigned to avoid this problem in the future. This also means that we don't need any delayed instantiation of the inner definition class in a grammar anymore. So the redesign not only helped fixing a long standing design problem, it helped to simplify things considerably.

All *Spirit.Qi* parser components have well defined attribute types. Grammars and rules are no exception. But since both need to be generic enough to be usable for any parser their attribute type has to be explicitly specified. In the example above the `roman` grammar and the rule `first` both have an `unsigned` attribute:

```
// grammar definition
template <typename Iterator>
struct roman : qi::grammar<Iterator, unsigned()> {...};

// rule definition
qi::rule<Iterator, unsigned()> first;
```

The used notation resembles the definition of a function type. This is very natural as you can think of the synthesized attribute of the grammar and the rule as of its 'return value'. In fact the rule and the grammar both 'return' an unsigned value - the value they matched.

Note

The function type notation allows to specify parameters as well. These are interpreted as the types of inherited attributes the rule or grammar expect to be passed during parsing. For more information please see the section about inherited and synthesized attributes for rules and grammars (Attributes).

If no attribute is desired none needs to be specified. The default attribute type for both, grammars and rules, is `unused_type`, which is a special placeholder type. Generally, using `unused_type` as the attribute of a parser is interpreted as 'this parser has no attribute'. This is mostly used for parsers applied to parts of the input not carrying any significant information, rather being delimiters or structural elements needed for correct interpretation of the input.

The last difference might seem to be rather cosmetic and insignificant. But it turns out that not having to specify which rule in a grammar is the start rule (by returning it from the function `start()`) also means that any rule in a grammar can be directly used as the start rule. Nevertheless, the grammar base class gets initialized with the rule it has to use as the start rule in case the grammar instance is directly used as a parser.

Style Guide

At some point, especially when there are lots of semantic actions attached to various points, the grammar tends to be quite difficult to follow. In order to keep an easy-to-read, consistent and aesthetically pleasing look to the Spirit code, the following coding styleguide is advised.

This coding style is adapted and extended from the ANTLR/PCCTS style and Boost Library Requirements and Guidelines and is the combined work of Joel de Guzman, Chris Uzdavinis, and Hartmut Kaiser.

- Rule names use std C++ (Boost) convention. The rule name may be very long.
- The '=' is neatly indented 4 spaces below. Like in Boost, use spaces instead of tabs.
- Breaking the operands into separate lines puts the semantic actions neatly to the right.
- Semicolon at the last line terminates the rule.
- The adjacent parts of a sequence should be indented accordingly to have all, what belongs to one level, at one indentation level.

```
program
    =   program_heading [heading_action]
        >> block [block_action]
        >> '.'
    |   another_sequence
        >> etc
    ;
```

- Prefer literals in the grammar instead of identifiers. e.g. `"program"` instead of `PROGRAM`, `'>='` instead of `GTE` and `'.'` instead of `DOT`. This makes it much easier to read. If this isn't possible (for instance where the used tokens must be identified through integers) capitalized identifiers should be used instead.

- Breaking the operands may not be needed for short expressions. e.g. `*(',' >> file_identifier)` as long as the line does not exceed 80 characters.
- If a sequence fits on one line, put spaces inside the parentheses to clearly separate them from the rules.

```
program_heading
    =   no_case["program"]
        >> identifier
        >> '('
        >> file_identifier
        >> *( ',' >> file_identifier )
        >> ')'
        >> ';'
    ;
```

- Nesting directives: If a rule does not fit on one line (80 characters) it should be continued on the next line intended by one level. The brackets of directives, semantic expressions (using Phoenix or LL lambda expressions) or parsers should be placed as follows.

```
identifier
    =   no_case
        [
            lexeme
            [
                alpha >> *(alnum | '_') [id_action]
            ]
        ]
   ;
```

- Nesting unary operators (e.g.Kleene star): Unary rule operators (Kleene star, `'!'`, `'+'` etc.) should be moved out one space before the corresponding indentation level, if this rule has a body or a sequence after it, which does not fit on on line. This makes the formatting more consistent and moves the rule 'body' at the same indentation level as the rule itself, highlighting the unary operator.

```
block
   =  *(   label_declaration_part
       |   constant_definition_part
       |   type_definition_part
       |   variable_declaration_part
       |   procedure_and_function_declaration_part
       )
       >> statement_part
   ;
```

Spirit Repository

The Spirit repository is a community effort collecting different reusable components (primitives, directives, grammars, etc.) for *Spirit.Qi* parsers and *Spirit.Karma* generators. All components in the repository have been peer reviewed or discussed on the Spirit General List. For more information about the repository see here.

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References

	Authors	Title, Publisher/link, Date Published
1.	Todd Veldhuizen	"Expression Templates". C++ Report, June 1995.
2.	Peter Naur (ed.)	"Report on the Algorithmic Language ALGOL 60". CACM, May 1960.
3.	ISO/IEC	"ISO-EBNF", ISO/IEC 14977: 1996(E).
4.	Richard J.Botting, Ph.D.	"XBNF" (citing Leu-Weiner, 1973). California State University, San Bernardino, 1998.
5.	James Coplien.	"Curiously Recurring Template Pattern". C++ Report, Feb. 1995.
6.	Thierry Geraud and Alexandre Duret-Lutz	Generic Programming Redesign of Patterns Proceedings of the 5th European Conference on Pattern Languages of Programs(EuroPLoP'2000) Irsee, Germany, July 2000.
7.	Geoffrey Furnish	"Disambiguated Glommable Expression Templates Reintroduced" C++ Report, May 2000
8.	Erich Gamma, Richard Helm, Ralph Jhonson, and John Vlissides	Design Patterns, Elements of Reusable Object-Oriented Software. Addison-Wesley, 1995.
9.	Alfred V. Aho, Revi Sethi, Feffrey D. Ulman	Compilers, Principles, Techniques and Tools Addison-Wesley, June 1987.
10.	Dick Grune and Ceriel Jacobs	Parsing Techniques: A Practical Guide. Ellis Horwood Ltd.: West Sussex, England, 1990. (electronic copy, 1998).
11.	T. J. Parr, H. G. Dietz, and W. E. Cohen	PCCTS Reference Manual (Version 1.00). School of Electrical Engineering, Purdue University, West Lafayette, August 1991.
12.	Adrian Johnstone and Elizabeth Scott.	RDP, A Recursive Descent Compiler Compiler. Technical Report CSD TR 97 25, Dept. of Computer Science, Egham, Surrey, England, Dec. 20, 1997.
13.	Adrian Johnstone	Languages and Architectures, Parser generators with backtrack or extended lookahead capability Department of Computer Science, Royal Holloway, University of London, Egham, Surrey, England
14.	Damian Conway	Parsing with C++ Classes. ACM SIGPLAN Notices, 29:1, 1994.

	Authors	Title, Publisher/link, Date Published
15.	Joel de Guzman	"Spirit Version 1.8", 1998-2003.
16.	S. Doaitse Swierstra and Luc Duponcheel	Deterministic, Error-Correcting Combinator Parsers Dept. of Computer Science, Utrecht University P.O.Box 80.089, 3508 TB Utrecht, The Netherland
17.	Bjarne Stroustrup	Generalizing Overloading for C++2000 Overload, Issue 25. April 1, 1998.
18.	Dr. John Maddock	Regex++ Documentation http://www.boost.org/libs/regex/index.htm
19.	Anonymous Edited by Graham Hutton	Frequently Asked Questions for comp.lang.functional. Edited by Graham Hutton, University of Nottingham.
20.	Hewlett-Packard	Standard Template Library Programmer's Guide., Hewlett-Packard Company, 1994
21.	Boost Libraries	Boost Libraries Documentation.
22.	Brian McNamara and Yannis Smaragdakis	FC++:Functional Programming in C++.
23.	Todd Veldhuizen	Techniques for Scientic C++.