# User-defined Literals (aka. Extensible Literals (revision 5)) 

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#### Abstract

This paper is Revision 5 of N1892, N2282, N2378, and N2750, and proposes additional forms of literals using modified syntax and semantics to provide user-defined literals. User-defined literals allow user-defined classes to provide new literal syntax, a feature previously available only for built-in types. It increases compatibility with C99 and future C enhancements, as well as more flexible $\mathrm{C}++$ literals.

The existing set of $(\mathrm{C}++03)$ literals is extended: Any literal may contain a userdefined suffix. Examples include "Hi"s, 1.2i, and 23_units. A user-defined "literal operator" function defines the mapping of such user-defined literals to actual values. Userdefined literals can produce values of both built-in types (e.g., double) and user-defined types (e.g., class types).

The proposal requires fairly localized changes to the core language. This revision makes a modification to the syntax of literal operators and drops most of the non-wording parts of the earlier papers. It also adds a paragraph in the library wording to reserve suffixes for future use by the standard library.


## 1 Proposed Wording

Modify the leading grammar rules of 2.4 lex.pptoken as indicated:

```
preprocessing-token:
    header-name
    identifier
    pp-number
    character-literal
    user-defined-character-literal
    string-literal
    user-defined-string-literal
    preprocessing-op-or-punc
    each non-white-space character that cannot be one of the above
```

Modify 2.4 lex.pptoken paragraph 2 as indicated:
2 [...] The categories of preprocessing token are: header names, identifiers, preprocessing numbers, character literals (including user-defined character literals), string literals (including user-defined string literals), preprocessing-op-or-punc, and single non-white-space characters that do not lexically match the other preprocessing token categories. [...]

Note to the editor: The Core Working Group suspects that the terms in 2.4 lex.pptoken paragraph 2 should not be italicized.

Modify the leading grammar rules of 2.9 lex.ppnumber as indicated:

```
pp-number:
    digit
    . digit
    pp-number digit
    pp-number identifier-nondigit
    pp-number e sign
    pp-number E sign
    pp-number.
```

Modify 2.13 lex.literal paragraph 1 as indicated:
1 There are several kinds of literals.20)
literal:
integer-literal
character-literal
floating-literal
string-literal
boolean-literal
user-defined-literal
Add a new section 2.13.7 lex.ext (no underlining to indicate insertion):

```
user-defined-literal:
    user-defined-integer-literal
    user-defined-floating-literal
    user-defined-string-literal
    user-defined-character-literal
user-defined-integer-literal:
    decimal-literal ud-suffix
    octal-literal ud-suffix
    hexadecimal-literal ud-suffix
user-defined-floating-literal:
    fractional-constant exponent-partopt ud-suffix
    digit-sequence exponent-part ud-suffix
user-defined-string-literal:
    string-literal ud-suffix
user-defined-character-literal:
    character-literal ud-suffix
ud-suffix:
    identifier
```

If a token matches both user-defined-literal and another literal kind, then it is treated as the latter. [Example: 123_km, 1.2LL, "Hello"s are all user-defined-literals, but 12 LL is an integer-literal. -end example]

1 A user-defined-literal is treated as a call to a literal operator or literal operator template (13.5.8 over.literal). To determine the form of this call for a given user-defined-literal $L$ with $u d$-suffix $X$, the literal-operator-id whose literal suffix identifier is $X$ is looked up in the context of $L$ using the rules for unqualified name lookup (3.4.1 basic.lookup.unqual). Let $S$ be the set of declarations found by this lookup. $S$ shall not be empty.

2 If $L$ is a user-defined-integer-literal, let $n$ be the literal without its $u d$-suffix. If $S$ contains a literal operator with parameter type unsigned long long, the literal $L$ is treated as a call of the form

```
operator "" X(nULL)
```

Otherwise, $S$ shall contain a raw literal operator or a literal operator template (13.5.8 over.literal), but not both. If $S$ contains a raw literal operator the literal $L$ is treated as a call of the form

$$
\text { operator "" } X(" n ")
$$

Otherwise ( $S$ contains a literal operator template), $L$ is treated as a call of the form

$$
\text { operator "" } X<' c_{1} ', ~ ' c_{2}^{\prime \prime}, \cdots, c_{k}^{\prime}>()
$$

where $n$ is the source character sequence $c_{1} c_{2} \ldots c_{k}$. [Note: The sequence $c_{1} c_{2} \ldots c_{k}$ can only contain characters from the basic source character set. -end note]

3 If $L$ is a user-defined-floating-literal, let $f$ be the literal without its ud-suffix. If $S$ contains a literal operator with parameter type long double, the literal $L$ is treated as a call of the form

$$
\text { operator "" } X(f \mathrm{~L})
$$

Otherwise, $S$ shall contain a raw literal operator or a literal operator template, but not both. If $S$ contains a raw literal operator the literal $L$ is treated as a call of the form

$$
\text { operator "" } X(" n \text { ") }
$$

Otherwise ( $S$ contains a literal operator template), $L$ is treated as a call of the form

$$
\text { operator "" } X<' c_{1} ', ~ ' c_{2} ', \cdots, c_{k}^{\prime}>()
$$

where $n$ is the source character sequence $c_{1} c_{2} \ldots c_{k}$. [Note: The sequence $c_{1} c_{2} \ldots c_{k}$ can only contain characters from the basic source character set. -end note]

4 If $L$ is a user-defined-string-literal, let str be the literal without its $u d$-suffix and let len be the number of characters (or code points) in str (i.e., its length excluding the terminating null character). The literal $L$ is treated as a call of the form

$$
\text { operator "" } X(\text { str, len })
$$

5 If $L$ is a user-defined-character-literal, let ch be the literal without its ud-suffix. The literal $L$ is treated as a call of the form

$$
\text { operator "" } X(c h)
$$

6 [Example:

```
long double operator "" w(long double);
std::string operator "" w(char16_t const*, size_t);
unsigned operator "" w(char const*);
int main() {
```

```
    1.2w; // calls operator "" w(1.2L)
    u"one"w; // calls operator "" w(u"one", 3)
    12w; // calls operator "" w("12")
    "two"w; // Error: No applicable literal operator
}
—end example]
```

7 In translation phase 6 (2.1 lex.phases), adjacent string literals are concatenated and user-defined-string-literals are considered string literals for that purpose. During concatenation, $u d$-suffixes are removed and ignored and the concatenation process occurs as described in 2.13.4 lex.string. At the end of phase 6 , if a string literal is the result of a concatenation involving at least one user-defined-string-literal, all the participating user-defined-string-literals shall have the same $u d$-suffix and that suffix is applied to the result of the concatenation.

8 [Example:

```
int main() {
    L"A" "B" "C"x; // Okay, same as L"ABC"x
    "P"x "Q" "R"y; // Error: two different ud-suffixes
}
-end example]
```

Modify 3 basic paragraph 1 as indicated:
7 Two names are the same if

- they are identifiers composed of the same character sequence; or
- they are the names of overloaded operator functions formed with the same operator; or
- they are the names of user-defined conversion functions formed with the same type; or
- they are the names of literal operators (13.5.8 over.literal) formed with the same literal suffix identifier.

Modify 5.1 expr.prim paragraph 1 as indicated:
1 unqualified-id:
identifier
operator-function-id
conversion-function-id
literal-operator-id
~ class-name
template-id

Modify 5.1 expr.prim paragraph 7 as indicated:
7 An identifier is an id-expression provided it has been suitably declared (clause 7). [Note: for operator-function-ids, see 13.5; for conversion-function-ids, see 12.3.2; for literal-operator-ids, see 13.5 .8 over.literal; for template-ids, see 14.2. A class-name prefixed by $\sim$ denotes a destructor; see 12.4. Within the definition of a non-static member function, an identifier that names a non-static member is transformed to a class member access expression (9.3.1). -end note] ...

Add a new section 13.5.8 over.literal (no underlining to indicate insertion):
literal-operator-id:
operator "" identifier
1 The identifier in a literal-operator-id is called a literal suffix identifier.
2 A declaration whose declarator-id is a literal-operator-id shall be a declaration of a namespace-scope function or function template (it could be a friend declaration (11.4 class.friend), an explicit instantiation or specialization of a function template, or a using-declarations (7.3.3 namespace.udecl). A function declared with a literal-operator-id is a literal operator. A function template declared with a literal-operatorid is a literal operator template.

3 The declaration of a literal operator shall have a parameter-declaration-clause equivalent to one of the following:

```
char const*
unsigned long long int
long double
char const*, std::size_t
wchar_t const*, std::size_t
char16_t const*, std::size_t
char32_t const*, std::size_t
```

4 A raw literal operator is a literal operator with a single parameter whose type is char const* (the first case in the list above).

5 The declaration of a literal operator template shall have an empty parameter-declaration-clause, and its template-parameter-list shall have a single templateparameter that is a non-type template parameter pack with element type char.

6 Literal operators and literal operator templates shall not have C language linkage.
7 [Note: Literal operators and literal operator templates are usually invoked implicitly through user-defined literals (lex.ext 2.13.6). However, except for the constraints described above, they are ordinary namespace-scope functions and function templates. In particular, they are looked up like ordinary functions and function
templates, and they follow the same overload resolution rules. Also, they can be declared inline or constexpr, they may have internal or external linkage, they can be called explicitly, their address can be taken, etc. -end note]

8 [Example:
void operator "" _km(long double); // Okay
string operator "" _i18n(char const*, size_t); // Okay
template<char ...>
int operator "" \u03C0(); // Okay (UCN for lowercase pi)
float operator ""E(char const*);
/ / Error: " " E (with no intervening space) is a single token
float operator " " B(char const*);
// Error: non-adjacent quotes
string operator "" 5X(char const*, size_t);
/ / Error: invalid literal suffix identifier
double operator "" _miles(double);
/ / Error: invalid parameter-declaration-clause
template<char ...> int operator "" j(char const*);
/ / Error: invalid parameter-declaration-clause
-end example]
Add a new section 17.6.4.3.6 usrlit.suffix as follows.
17.6.4.3.6 User-defined literal suffixes [usrlit.suffix]

1 Literal suffix identifiers that do not start with an underscore are reserved for future standardization.

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