Programming Language — C

ABSTRACT

[0]

(Cover sheet to be provided by ISO Secretariat.)

This International Standard specifies the form and establishes the interpretation of programs expressed in the programming language C. Its purpose is to promote portability, reliability, maintainability, and efficient execution of C language programs on a variety of computing systems.

[0] Clauses are included that detail the C language itself and the contents of the C language execution library. Annexes summarize aspects of both of them, and enumerate factors that influence the portability of C programs.

[0] Although this International Standard is intended to guide knowledgeable C language programmers as well as implementors of C language translation systems, the document itself is not designed to serve as a tutorial.

Introduction

[2] With the introduction of new devices and extended character sets, new features may be added to this International Standard. Subclauses in the language and library clauses warn implementors and programmers of usages which, though valid in themselves, may conflict with future additions.

[3] Certain features are *obsolescent*, which means that they may be considered for withdrawal in future revisions of this International Standard. They are retained because of their widespread use, but their use in new implementations (for implementation features) or new programs (for language [6.9] or library features [7.17]) is discouraged.

[4] This International Standard is divided into four major subdivisions:

— the introduction and preliminary elements;

— the characteristics of environments that translate and execute C programs;

— the language syntax, constraints, and semantics;

— the library facilities.

[5] Examples are provided to illustrate possible forms of the constructions described. Footnotes are provided to emphasize consequences of the rules described in that subclause or elsewhere in this International Standard. References are used to refer to other related subclauses. A set of annexes summarizes information contained in this International Standard. The introduction, the examples, the footnotes, the references, and the annexes are not part of this International Standard.

[6] The language clause (clause 7) is derived from ‘‘The C Reference Manual’’ (see annex A).

[7] The library clause (clause 8) is based on the *1984 /usr/group Standard* (see annex A).

Contents

Programming Language — C

1. Scope

[1] This International Standard specifies the form and establishes the interpretation of programs written in the C programming language.[1] It specifies

— the representation of C programs;

— the syntax and constraints of the C language;

— the semantic rules for interpreting C programs;

— the representation of input data to be processed by C programs;

— the representation of output data produced by C programs;

— the restrictions and limits imposed by a conforming implementation of C.

[2] This International Standard does not specify

— the mechanism by which C programs are transformed for use by a data-processing system;

— the mechanism by which C programs are invoked for use by a data-processing system;

— the mechanism by which input data are transformed for use by a C program;

— the mechanism by which output data are transformed after being produced by a C program;

— the size or complexity of a program and its data that will exceed the capacity of any specific data-processing system or the capacity of a particular processor;

— all minimal requirements of a data-processing system that is capable of supporting a conforming implementation.

1. This International Standard is designed to promote the portability of C programs among a variety of data-processing systems. It is intended for use by implementors and programmers. It is accompanied by a Rationale document that explains many of the decisions of the Technical Committee that produced it.

2. Normative references

[1] The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

> ISO 646:1983, *Information processing — ISO 7-bit coded character set for information interchange*.
>
> ISO 4217:1987, *Codes for the representation of currencies and funds*.

3. Definitions and conventions

[1] In this International Standard, ''shall'' is to be interpreted as a requirement on an implementation or on a program; conversely, ''shall not'' is to be interpreted as a prohibition.

[2] For the purposes of this International Standard, the following definitions apply. Other terms are defined at their first appearance, indicated by *italic* type. Terms explicitly defined in this International Standard are not to be presumed to refer implicitly to similar terms defined elsewhere. Terms not defined in this International Standard are to be interpreted according to ISO 2382.

3.1 alignment: **[1]** A requirement that objects of a particular type be located on storage boundaries with addresses that are particular multiples of a byte address.

3.2 argument: **[1]** An expression in the comma-separated list bounded by the parentheses in a function call expression, or a sequence of preprocessing tokens in the comma-separated list bounded by the parentheses in a function-like macro invocation. Also known as ''actual argument'' or ''actual parameter.''

3.3 bit: **[1]** The unit of data storage in the execution environment large enough to hold an object that may have one of two values. It need not be possible to express the address of each individual bit of an object.

3.4 byte: **[1]** The unit of data storage large enough to hold any member of the basic character set of the execution environment. It shall be possible to express the address of each individual byte of an object uniquely. A byte is composed of a contiguous sequence of bits, the number of which is implementation-defined. The least significant bit is called the *low-order* bit; the most significant bit is called the *high-order* bit.

3.5 character: **[1]** A bit representation that fits in a byte. The representation of each member of the basic character set in both the source and execution environments shall fit in a byte.

3.6 constraints: **[1]** Syntactic and semantic restrictions by which the exposition of language elements is to be interpreted.

3.7 correctly rounded result: **[1]** A representation in the result format that is nearest in value, subject to the effective rounding mode, to what the result would be given unlimited range and precision.

3.8 diagnostic message: **[1]** A message belonging to an implementation-defined subset of the implementation's message output.

3.9 forward references: **[1]** References to later subclauses of this International Standard that contain additional information relevant to this subclause.

3.10 implementation: **[1]** A particular set of software, running in a particular translation environment under particular control options, that performs translation of programs for, and supports execution of functions in, a particular execution environment.

3.11 implementation-defined behavior: **[1]** Behavior, for a correct program construct and correct data, that depends on the characteristics of the implementation and that each implementation shall document.

3.12 implementation limits: **[1]** Restrictions imposed upon programs by the implementation.

3.13 locale-specific behavior: **[1]** Behavior that depends on local conventions of nationality, culture, and language that each implementation shall document.

3.14 multibyte character: **[1]** A sequence of one or more bytes representing a member of the extended character set of either the source or the execution environment. The extended character set is a superset of the basic character set.

3.15 object: **[1]** A region of data storage in the execution environment, the contents of which can represent values. Except for bit-fields, objects are composed of contiguous sequences of one or more bytes, the number, order, and encoding of which are either explicitly specified or implementation-defined. When referenced, an object may be interpreted as having a particular type; see 6.2.2.1.

3.16 parameter: **[1]** An object declared as part of a function declaration or definition that acquires a value on entry to the function, or an identifier from the comma-separated list bounded by the parentheses immediately following the macro name in a function-like macro definition. Also known as ‘‘formal argument’’ or ‘‘formal parameter.’’

3.17 recommended practice: **[1]** Sections so entitled contain specification that is strongly recommended as being in keeping with the intent of the standard, but that may be impractical for some implementations.

3.18 undefined behavior: **[1]** Behavior, upon use of a nonportable or erroneous program construct, of erroneous data, or of indeterminately valued objects, for which this International Standard imposes no requirements. Permissible undefined behavior ranges from ignoring the situation completely with unpredictable results, to behaving during translation or program execution in a documented manner characteristic of the environment (with or without the issuance of a diagnostic message), to terminating a translation or execution (with the issuance of a diagnostic message).

[2] If a ‘‘shall’’ or ‘‘shall not’’ requirement that appears outside of a constraint is violated, the behavior is undefined. Undefined behavior is otherwise indicated in this International Standard by the words ‘‘undefined behavior’’ or by the omission of any explicit definition of behavior. There is no difference in emphasis among these three; they all describe ‘‘behavior that is undefined.’’

3.19 unspecified behavior: **[1]** Behavior, for a correct program construct and correct data, for which this International Standard explicitly imposes no requirements.

Examples

[2]

1. An example of unspecified behavior is the order in which the arguments to a function are evaluated.
2. An example of undefined behavior is the behavior on integer overflow.
3. An example of implementation-defined behavior is the propagation of the high-order bit when a signed integer is shifted right.
4. An example of locale-specific behavior is whether the **`islower`** function returns true for characters other than the 26 lowercase English letters.

Forward references: bitwise shift operators (6.3.7), expressions (6.3), function calls (6.3.2.2), the **`islower`** function (7.3.1.6), localization (7.5).

4. Compliance

[1] A *strictly conforming program* shall use only those features of the language and library specified in this International Standard. It shall not produce output dependent on any unspecified, undefined, or implementation-defined behavior, and shall not exceed any minimum implementation limit.

[2] The two forms of *conforming implementation* are hosted and freestanding. A *conforming hosted implementation* shall accept any strictly conforming program. A *conforming freestanding implementation* shall accept any strictly conforming program in which the use of the features specified in the library clause (clause 7) is confined to the contents of the standard headers **`<float.h>`**, **`<limits.h>`**, **`<stdarg.h>`**, **`<stddef.h>`**, and **`<iso646.h>`**. A conforming implementation may have extensions (including additional library functions), provided they do not alter the behavior of any strictly conforming program.[2]

2. This implies that a conforming implementation reserves no identifiers other than those explicitly reserved in this International Standard.

[3] A *conforming program* is one that is acceptable to a conforming implementation.[3]

[4] An implementation shall be accompanied by a document that defines all implementation-defined characteristics and all extensions.

Forward references: limits **`<float.h>`** and **`<limits.h>`** (7.1.5), variable arguments **`<stdarg.h>`** (7.10), common definitions **`<stddef.h>`** (7.1.6), alternate spellings **`<iso646.h>`** (7.15).

3. Strictly conforming programs are intended to be maximally portable among conforming implementations. Conforming programs may depend upon nonportable features of a conforming implementation.

5. Environment

[1] An implementation translates C source files and executes C programs in two data-processing-system environments, which will be called the *translation environment* and the *execution environment* in this International Standard. Their characteristics define and constrain the results of executing conforming C programs constructed according to the syntactic and semantic rules for conforming implementations.

Forward references: In the environment clause (clause 5), only a few of many possible forward references have been noted.

5.1 Conceptual models

5.1.1 Translation environment

5.1.1.1 Program structure

[1] A C program need not all be translated at the same time. The text of the program is kept in units called *source files* in this International Standard. A source file together with all the headers and source files included via the preprocessing directive **`#include`**, less any source lines skipped by any of the conditional inclusion preprocessing directives, is called a *translation unit*. Previously translated translation units may be preserved individually or in libraries. The separate translation units of a program communicate by (for example) calls to functions whose identifiers have external linkage, manipulation of objects whose identifiers have external linkage, or manipulation of data files. Translation units may be separately translated and then later linked to produce an executable program.

Forward references: conditional inclusion (6.8.1), linkages of identifiers (6.1.2.2), source file inclusion (6.8.2).

5.1.1.2 Translation phases

[1] The precedence among the syntax rules of translation is specified by the following phases.[4]

1. Physical source file characters are mapped to the source character set (introducing new-line characters for end-of-line indicators) if necessary. Trigraph sequences are replaced by corresponding single-character internal representations.

2. Each instance of a new-line character and an immediately preceding backslash character is deleted, splicing physical source lines to form logical source lines. A source file that is not empty shall end in a new-line character, which shall not be immediately preceded by a backslash character.

4. Implementations must behave as if these separate phases occur, even though many are typically folded together in practice.

3. The source file is decomposed into preprocessing tokens[5] and sequences of white-space characters (including comments). A source file shall not end in a partial preprocessing token or comment. Each comment is replaced by one space character. New-line characters are retained. Whether each nonempty sequence of white-space characters other than new-line is retained or replaced by one space character is implementation-defined.

4. Preprocessing directives are executed, macro invocations are expanded, and **`pragma`** unary operator expressions are executed. A **`#include`** preprocessing directive causes the named header or source file to be processed from phase 1 through phase 4, recursively. All preprocessing directives are then deleted. |

5. Each source character set member and escape sequence in character constants and string literals is converted to a member of the execution character set.

6. Adjacent character string literal tokens are concatenated and adjacent wide string literal tokens are concatenated.

7. White-space characters separating tokens are no longer significant. Each preprocessing token is converted into a token. The resulting tokens are syntactically and semantically analyzed and translated.

8. All external object and function references are resolved. Library components are linked to satisfy external references to functions and objects not defined in the current translation. All such translator output is collected into a program image which contains information needed for execution in its execution environment.

Forward references: lexical elements (6.1), preprocessing directives (6.8), trigraph sequences (5.2.1.1).

5.1.1.3 Diagnostics

[1] A conforming implementation shall produce at least one diagnostic message (identified in an implementation-defined manner) for every translation unit that contains a violation of any syntax rule or constraint, even if the behavior is also explicitly specified as undefined or implementation-defined. Diagnostic messages need not be produced in other circumstances.[6] *

Example

[2] An implementation shall issue a diagnostic for the translation unit: *

5. As described in 6.1, the process of dividing a source file's characters into preprocessing tokens is context-dependent. For example, see the handling of **`<`** within a **`#include`** preprocessing directive.

6. The intent is that an implementation should identify the nature of, and where possible localize, each violation. Of course, an implementation is free to produce any number of diagnostics as long as a valid program is still correctly translated. It may also successfully translate an invalid program.

```
char i;
int i;
```

because in those cases where wording in this International Standard describes the behavior for a construct as being both a constraint error and resulting in undefined behavior, the constraint error shall be diagnosed.

5.1.2 Execution environments

[1] Two execution environments are defined: *freestanding* and *hosted*. In both cases, *program startup* occurs when a designated C function is called by the execution environment. All objects in static storage shall be *initialized* (set to their initial values) before program startup. The manner and timing of such initialization are otherwise unspecified. *Program termination* returns control to the execution environment.

Forward references: initialization (6.5.7).

5.1.2.1 Freestanding environment

[1] In a freestanding environment (in which C program execution may take place without any benefit of an operating system), the name and type of the function called at program startup are implementation-defined. Any library facilities available to a freestanding program are implementation-defined.

[2] The effect of program termination in a freestanding environment is implementation-defined.

5.1.2.2 Hosted environment

[1] A hosted environment need not be provided, but shall conform to the following specifications if present.

5.1.2.2.1 Program startup

[1] The function called at program startup is named **`main`**. The implementation declares no prototype for this function. It can be defined with no parameters:

```
int main(void) { /*...*/ }
```

or with two parameters (referred to here as **`argc`** and **`argv`**, though any names may be used, as they are local to the function in which they are declared):

```
int main(int argc, char *argv[]) { /*...*/ }
```

[2] If they are defined, the parameters to the **`main`** function shall obey the following constraints:

— The value of **`argc`** shall be nonnegative.

— **`argv[argc]`** shall be a null pointer.

— If the value of **`argc`** is greater than zero, the array members **`argv[0]`** through **`argv[argc-1]`** inclusive shall contain pointers to strings, which are given implementation-defined values by the host environment prior to program startup. The intent is to supply to the program information determined prior to program startup from elsewhere in the hosted environment. If the host environment is not capable of supplying strings with letters in both uppercase and lowercase, the implementation shall ensure that the strings are received in lowercase.

— If the value of **`argc`** is greater than zero, the string pointed to by **`argv[0]`** represents the *program name*; **`argv[0][0]`** shall be the null character if the program name is not available from the host environment. If the value of **`argc`** is greater than one, the strings pointed to by **`argv[1]`** through **`argv[argc-1]`** represent the *program parameters*.

— The parameters **`argc`** and **`argv`** and the strings pointed to by the **`argv`** array shall be modifiable by the program, and retain their last-stored values between program startup and program termination.

5.1.2.2.2 Program execution

[1] In a hosted environment, a program may use all the functions, macros, type definitions, and objects described in the library clause (clause 7).

5.1.2.2.3 Program termination

[1] A return from the initial call to the **`main`** function is equivalent to calling the **`exit`** function with the value returned by the **`main`** function as its argument. If the **`main`** function executes a return that specifies no value, the termination status returned to the host environment is undefined.[7]

Forward references: definition of terms (7.1.1), the **`exit`** function (7.12.4.3).

5.1.2.3 Program execution

[1] The semantic descriptions in this International Standard describe the behavior of an abstract machine in which issues of optimization are irrelevant.

[2] Accessing a volatile object, modifying an object, modifying a file, or calling a function that does any of those operations are all *side effects*, which are changes in the state of the execution environment. Evaluation of an expression may produce side effects. At certain specified points in the execution sequence called *sequence points*, all side effects of previous evaluations shall be complete and no side effects of subsequent evaluations shall have taken place.

[3] In the abstract machine, all expressions are evaluated as specified by the semantics. An actual implementation need not evaluate part of an expression if it can deduce that its value is not used and that no needed side effects are produced (including any

7. In accordance with subclause 6.1.2.4, objects with automatic storage duration declared in **`main`** will no longer have storage guaranteed to be reserved in the former case even where they would in the latter.

caused by calling a function or accessing a volatile object).

[4] When the processing of the abstract machine is interrupted by receipt of a signal, only the values of objects as of the previous sequence point may be relied on. Objects that may be modified between the previous sequence point and the next sequence point need not have received their correct values yet.

[5] An instance of each object with automatic storage duration is associated with each entry into its block. Such an object exists and retains its last-stored value during the execution of the block and while the block is suspended (by a call of a function or receipt of a signal).

[6] The least requirements on a conforming implementation are:

— At sequence points, volatile objects are stable in the sense that previous evaluations are complete and subsequent evaluations have not yet occurred.

— At program termination, all data written into files shall be identical to the result that execution of the program according to the abstract semantics would have produced.

— The input and output dynamics of interactive devices shall take place as specified in 7.11.3. The intent of these requirements is that unbuffered or line-buffered output appear as soon as possible, to ensure that prompting messages actually appear prior to a program waiting for input.

[7] What constitutes an interactive device is implementation-defined.

[8] More stringent correspondences between abstract and actual semantics may be defined by each implementation.

Examples

[9]

1. An implementation might define a one-to-one correspondence between abstract and actual semantics: at every sequence point, the values of the actual objects would agree with those specified by the abstract semantics. The keyword **`volatile`** would then be redundant.

   [10] Alternatively, an implementation might perform various optimizations within each translation unit, such that the actual semantics would agree with the abstract semantics only when making function calls across translation unit boundaries. In such an implementation, at the time of each function entry and function return where the calling function and the called function are in different translation units, the values of all externally linked objects and of all objects accessible via pointers therein would agree with the abstract semantics. Furthermore, at the time of each such function entry the values of the parameters of the called function and of all objects accessible via pointers therein would agree with the abstract semantics. In this type of implementation, objects referred to by interrupt service routines activated by the **`signal`** function would require explicit specification of **volatile** storage, as well as other implementation-defined restrictions.

2. In executing the fragment

```
char c1, c2;
/*...*/
c1 = c1 + c2;
```

the ‘‘integral promotions’’ require that the abstract machine promote the value of each variable to **int** size and then add the two **int**s and truncate the sum. Provided the addition of two **char**s can be done without creating an overflow exception, the actual execution need only produce the same result, possibly omitting the promotions.

3. Similarly, in the fragment

```
float f1, f2;
double d;
/*...*/
f1 = f2 * d;
```

the multiplication may be executed using single-precision arithmetic if the implementation can ascertain that the result would be the same as if it were executed using double-precision arithmetic (for example, if **d** were replaced by the constant **2.0**, which has type **double**). Alternatively, an operation involving only **int**s or **float**s may be executed using double-precision operations if neither range nor precision is lost thereby.

4. To illustrate the grouping behavior of expressions, in the following fragment

```
int a, b;
/*...*/
a = a + 32760 + b + 5;
```

the expression statement behaves exactly the same as

```
a = (((a + 32760) + b) + 5);
```

due to the associativity and precedence of these operators. Thus, the result of the sum ‘‘**(a + 32760)**’’ is next added to **b**, and that result is then added to **5** which results in the value assigned to **a**. On a machine in which overflows produce an exception and in which the range of values representable by an **int** is [−32768,+32767], the implementation cannot rewrite this expression as

```
a = ((a + b) + 32765);
```

since if the values for **a** and **b** were, respectively, −32754 and −15, the sum **a + b** would produce an exception while the original expression would not; nor can the expression be rewritten either as

```
a = ((a + 32765) + b);
```

or

```
a = (a + (b + 32765));
```

since the values for **a** and **b** might have been, respectively, 4 and −8 or −17 and 12. However on a machine in which overflows do not produce an exception and in which the results of overflows are reversible, the above expression statement can be rewritten by the implementation in any of the above ways because the same result will occur.

5. The grouping of an expression does not completely determine its evaluation. In the following fragment

```
#include <stdio.h>
int sum;
char *p;
/*...*/
sum = sum * 10 - '0' + (*p++ = getchar());
```

the expression statement is grouped as if it were written as

```
sum = (((sum * 10) - '0') + ((*(p++)) = (getchar())));
```

but the actual increment of **p** can occur at any time between the previous sequence point and the next sequence point (the **;**), and the call to **getchar** can occur at any point prior to the need of its returned value.

Forward references: compound statement, or block (6.6.2), expressions (6.3), files (7.11.3), sequence points (6.3, 6.6), the **signal** function (7.9), type qualifiers (6.5.3).

5.2 Environmental considerations

5.2.1 Character sets

[1] Two sets of characters and their associated collating sequences shall be defined: the set in which source files are written, and the set interpreted in the execution environment. The values of the members of the execution character set are implementation-defined; any additional members beyond those required by this subclause are locale-specific.

[2] In a character constant or string literal, members of the execution character set shall be represented by corresponding members of the source character set or by *escape sequences* consisting of the backslash `\` followed by one or more characters. A byte with all bits set to 0, called the *null character*, shall exist in the basic execution character set; it is used to terminate a character string literal.

[3] Both the basic source and basic execution character sets shall have at least the following members: the 26 uppercase letters of the English alphabet

```
A B C D E F G H I J K L M
N O P Q R S T U V W X Y Z
```

the 26 lowercase letters of the English alphabet

```
a b c d e f g h i j k l m
n o p q r s t u v w x y z
```

the 10 decimal digits

```
0 1 2 3 4 5 6 7 8 9
```

the following 29 graphic characters

```
! " # % & ' ( ) * + , - . / :
; < = > ? [ \ ] ^ _ { | } ~
```

the space character, and control characters representing horizontal tab, vertical tab, and form feed. In both the source and execution basic character sets, the value of each character after `0` in the above list of decimal digits shall be one greater than the value of the previous. In source files, there shall be some way of indicating the end of each line of text; this International Standard treats such an end-of-line indicator as if it were a single new-line character. In the execution character set, there shall be control characters representing alert, backspace, carriage return, and new line. If any other characters are encountered in a source file (except in a character constant, a string literal, a header name, a comment, or a preprocessing token that is never converted to a token), the behavior is undefined.

Forward references: character constants (6.1.3.4), preprocessing directives (6.8), string literals (6.1.4), comments (6.1.9).

5.2.1.1 Trigraph sequences

[1] All occurrences in a source file of the following sequences of three characters (called *trigraph sequences*[8]) are replaced with the corresponding single character.

```
??=  #
??(  [
??/  \
??)  ]
??'  ^
??<  {
??!  |
??>  }
??-  ~
```

No other trigraph sequences exist. Each `?` that does not begin one of the trigraphs listed above is not changed.

Example

[2] The following source line

```
printf("Eh???/n");
```

becomes (after replacement of the trigraph sequence `??/`)

```
printf("Eh?\n");
```

5.2.1.2 Multibyte characters

[1] The source character set may contain multibyte characters, used to represent members of the extended character set. The execution character set may also contain multibyte characters, which need not have the same encoding as for the source character set. For both character sets, the following shall hold:

— The single-byte characters defined in 5.2.1 shall be present.

— The presence, meaning, and representation of any additional members is locale-specific.

— A multibyte character may have a *state-dependent encoding*, wherein each sequence of multibyte characters begins in an *initial shift state* and enters other locale-specific *shift states* when specific multibyte characters are encountered in the sequence. While in the initial shift state, all single-byte characters retain their usual interpretation and do not alter the shift state. The interpretation for subsequent bytes in the sequence is a function of the current shift state.

8. The trigraph sequences enable the input of characters that are not defined in the Invariant Code Set as described in ISO 646:1983, which is a subset of the seven-bit ASCII code set.

— A byte with all bits zero shall be interpreted as a null character independent of shift state.

— A byte with all bits zero shall not occur in the second or subsequent bytes of a multibyte character.

[2] For the source character set, the following shall hold:

— A comment, string literal, character constant, or header name shall begin and end in the initial shift state.

— A comment, string literal, character constant, or header name shall consist of a sequence of valid multibyte characters.

5.2.2 Character display semantics

[1] The *active position* is that location on a display device where the next character output by the **`fputc`** function would appear. The intent of writing a printable character (as defined by the **`isprint`** function) to a display device is to display a graphic representation of that character at the active position and then advance the active position to the next position on the current line. The direction of writing is locale-specific. If the active position is at the final position of a line (if there is one), the behavior is unspecified.

[2] Alphabetic escape sequences representing nongraphic characters in the execution character set are intended to produce actions on display devices as follows:

`\a` (*alert*) Produces an audible or visible alert. The active position shall not be changed.

`\b` (*backspace*) Moves the active position to the previous position on the current line. If the active position is at the initial position of a line, the behavior is unspecified.

`\f` (*form feed*) Moves the active position to the initial position at the start of the next logical page.

`\n` (*new line*) Moves the active position to the initial position of the next line.

`\r` (*carriage return*) Moves the active position to the initial position of the current line.

`\t` (*horizontal tab*) Moves the active position to the next horizontal tabulation position on the current line. If the active position is at or past the last defined horizontal tabulation position, the behavior is unspecified.

`\v` (*vertical tab*) Moves the active position to the initial position of the next vertical tabulation position. If the active position is at or past the last defined vertical tabulation position, the behavior is unspecified.

[3] Each of these escape sequences shall produce a unique implementation-defined value which can be stored in a single **`char`** object. The external representations in a text file need not be identical to the internal representations, and are outside the scope of this International Standard.

Forward references: the **fputc** function (7.11.7.3), the **isprint** function (7.3.1.7). |

5.2.3 Signals and interrupts

[1] Functions shall be implemented such that they may be interrupted at any time by a signal, or may be called by a signal handler, or both, with no alteration to earlier, but still active, invocations' control flow (after the interruption), function return values, or objects with automatic storage duration. All such objects shall be maintained outside the *function image* (the instructions that comprise the executable representation of a function) on a per-invocation basis.

[2] The functions in the standard library are not guaranteed to be reentrant and may modify objects with static storage duration.

5.2.4 Environmental limits

[1] Both the translation and execution environments constrain the implementation of language translators and libraries. The following summarizes the environmental limits on a conforming implementation.

5.2.4.1 Translation limits

[1] The implementation shall be able to translate and execute at least one program that contains at least one instance of every one of the following limits:[9]

— 15 nesting levels of compound statements, iteration statements, and selection statements *

— 8 nesting levels of conditional inclusion

— 12 pointer, array, and function declarators (in any combinations) modifying an arithmetic, a structure, a union, or an incomplete type in a declaration

— 31 nesting levels of parenthesized declarators within a full declarator

— 32 nesting levels of parenthesized expressions within a full expression

— 31 significant initial characters in an internal identifier or a macro name

— 6 significant initial characters in an external identifier

— 511 external identifiers in one translation unit

— 127 identifiers with block scope declared in one block

— 1024 macro identifiers simultaneously defined in one translation unit

— 31 parameters in one function definition

---

9. Implementations should avoid imposing fixed translation limits whenever possible.

— 31 arguments in one function call

— 31 parameters in one macro definition

— 31 arguments in one macro invocation

— 509 characters in a logical source line

— 509 characters in a character string literal or wide string literal (after concatenation)

— 32767 bytes in an object (in a hosted environment only)

— 8 nesting levels for **`#include`**d files

— 257 **`case`** labels for a **`switch`** statement (excluding those for any nested **`switch`** statements)

— 127 members in a single structure or union

— 127 enumeration constants in a single enumeration

— 15 levels of nested structure or union definitions in a single struct-declaration-list

5.2.4.2 Numerical limits

[1] A conforming implementation shall document all the limits specified in this subclause, which shall be specified in the headers **`<limits.h>`** and **`<float.h>`**.

5.2.4.2.1 Sizes of integral types `<limits.h>`

[1] The values given below shall be replaced by constant expressions suitable for use in **`#if`** preprocessing directives. Moreover, except for **`CHAR_BIT`** and **`MB_LEN_MAX`**, the following shall be replaced by expressions that have the same type as would an expression that is an object of the corresponding type converted according to the integral promotions. Their implementation-defined values shall be equal or greater in magnitude (absolute value) to those shown, with the same sign.

— number of bits for smallest object that is not a bit-field (byte)
`CHAR_BIT` **`8`**

— minimum value for an object of type **`signed char`**
`SCHAR_MIN` **`-127`**

— maximum value for an object of type **`signed char`**
`SCHAR_MAX` **`+127`**

— maximum value for an object of type **`unsigned char`**
`UCHAR_MAX` **`255`**

— minimum value for an object of type **`char`**
`CHAR_MIN` *see below*

— maximum value for an object of type **`char`**
`CHAR_MAX` *see below*

— maximum number of bytes in a multibyte character, for any supported locale
`MB_LEN_MAX` **`1`**

— minimum value for an object of type **`short int`**
`SHRT_MIN` **`-32767`**

— maximum value for an object of type **`short int`**
`SHRT_MAX` **`+32767`**

— maximum value for an object of type **`unsigned short int`**
`USHRT_MAX` **`65535`**

— minimum value for an object of type **`int`**
`INT_MIN` **`-32767`**

— maximum value for an object of type **`int`**
`INT_MAX` **`+32767`**

— maximum value for an object of type **`unsigned int`**
`UINT_MAX` **`65535`**

— minimum value for an object of type **`long int`**
`LONG_MIN` **`-2147483647`**

— maximum value for an object of type **`long int`**
`LONG_MAX` **`+2147483647`**

— maximum value for an object of type **`unsigned long int`**
`ULONG_MAX` **`4294967295`**

— minimum value for an object of type **`long long int`**
`LLONG_MIN` **`-9223372036854775807`**

— maximum value for an object of type **`long long int`**
`LLONG_MAX` **`+9223372036854775807`**

— maximum value for an object of type **`unsigned long long int`**
`ULLONG_MAX` **`18446744073709551615`**

[2] If the value of an object of type **`char`** is treated as a signed integer when used in an expression, the value of **`CHAR_MIN`** shall be the same as that of **`SCHAR_MIN`** and the value of **`CHAR_MAX`** shall be the same as that of **`SCHAR_MAX`**. Otherwise, the value of **`CHAR_MIN`** shall be 0 and the value of **`CHAR_MAX`** shall be the same as that of **`UCHAR_MAX`**.[10]

10. See 6.1.2.5.

5.2.4.2.2 Characteristics of floating types `<float.h>`

The characteristics of floating types are defined in terms of a model that describes a representation of floating-point numbers and values that provide information about an implementation's floating-point arithmetic.[11] The following parameters are used to define the model for each floating-point type:

s	sign (± 1)
b	base or radix of exponent representation (an integer > 1)
e	exponent (an integer between a minimum $e_{\min}$ and a maximum $e_{\max}$)
p	precision (the number of base-b digits in the significand)
f_k	nonnegative integers less than b (the significand digits)

[2] A normalized floating-point number x ($f_1 > 0$ if $x \neq 0$) is defined by the following model:

$$x = s \times b^e \times \sum_{k=1}^{p} f_k \times b^{-k}, \quad e_{\min} \leq e \leq e_{\max}$$

[3]

Of the values in the **`<float.h>`** header, **`FLT_EVAL_METHOD`** and **`FLT_RADIX`** shall be constant expressions suitable for use in **`#if`** preprocessing directives; all other values need not be constant expressions. All except **`FLT_EVAL_METHOD`**, **`FLT_RADIX`**,**and `FLT_ROUNDS`** have separate names for all three floating-point types. The floating-point model representation is provided for all values except **`FLT_EVAL_METHOD`**[12] and **`FLT_ROUNDS`**[13].

[4] The rounding mode for floating-point addition is characterized by the value of **`FLT_ROUNDS`**:

-1	indeterminable
0	toward zero
1	to nearest
2	toward positive infinity
3	toward negative infinity

All other values for **`FLT_ROUNDS`** characterize implementation-defined rounding behavior.

---

11. The floating-point model is intended to clarify the description of each floating-point characteristic and does not require the floating-point arithmetic of the implementation to be identical.

12. The evaluation method determines evaluation formats of expressions involving all floating types, not just real types. For example, if is **`1`**, then the product of two **`float complex`** operands is represented in the **`double complex`** format, and its parts are evaluated to **`double`**.

13. Evaluation of **`FLT_ROUNDS`** correctly reflects any execution-time change of rounding mode through the function fesetround in **`<fenv.h>`**.

[5] The values of operations with floating operands and subject to the usual arithmetic conversions and of floating constants are evaluated to a format whose range and precision may be greater than required by the type. The use of evaluation formats is characterized by the value of **`FLT_EVAL_METHOD`**:

-1 indeterminable;

0 evaluate all operations and constants just to the range and precision of the type;

1 evaluate operations and constants of type float and double to the range and precision of the double type, evaluate long double operations and constants to the range and precision of the long double type;

2 evaluate all operations and constants to the range and precision of the long double type.

All other negative values for FLT_EVAL_METHOD characterize implementation-defined behavior.

[6] The values given in the following list shall be replaced by implementation-defined expressions that shall be equal or greater in magnitude (absolute value) to those shown, with the same sign:

— radix of exponent representation, b
`FLT_RADIX` **2**

— number of base-**`FLT_RADIX`** digits in the floating-point significand, p

`FLT_MANT_DIG`
`DBL_MANT_DIG`
`LDBL_MANT_DIG`

— number of decimal digits, q, such that any floating-point number with q decimal digits can be rounded into a floating-point number with p radix b digits and back again without change to the q decimal digits,

$$\left\lfloor (p - 1) \times \log_{10} b \right\rfloor + \begin{cases} 1 & \text{if } b \text{ is a power of 10} \\ 0 & \text{otherwise} \end{cases}$$

`FLT_DIG` **6**
`DBL_DIG` **10**
`LDBL_DIG` **10**

— minimum negative integer such that **`FLT_RADIX`** raised to that power minus 1 is a normalized floating-point number, $e_{\min}$

`FLT_MIN_EXP`
`DBL_MIN_EXP`
`LDBL_MIN_EXP`

— minimum negative integer such that 10 raised to that power is in the range of normalized floating-point numbers, $\left\lceil \log_{10} b^{e_{\min}-1} \right\rceil$

FLT_MIN_10_EXP	**-37**
DBL_MIN_10_EXP	**-37**
LDBL_MIN_10_EXP	**-37**

— maximum integer such that **FLT_RADIX** raised to that power minus 1 is a representable finite floating-point number, $e_{\max}$

FLT_MAX_EXP
DBL_MAX_EXP
LDBL_MAX_EXP

— maximum integer such that 10 raised to that power is in the range of representable finite floating-point numbers, $\lfloor \log_{10}((1 - b^{-p}) \times b^{e_{\max}}) \rfloor$

FLT_MAX_10_EXP	**+37**
DBL_MAX_10_EXP	**+37**
LDBL_MAX_10_EXP	**+37**

[7] The values given in the following list shall be replaced by implementation-defined expressions with values that shall be equal to or greater than those shown:

— maximum representable finite floating-point number, $(1 - b^{-p}) \times b^{e_{\max}}$

FLT_MAX	**1E+37**
DBL_MAX	**1E+37**
LDBL_MAX	**1E+37**

[8] The values given in the following list shall be replaced by implementation-defined expressions with values that shall be equal to or less than those shown:

— the difference between 1 and the least value greater than 1 that is representable in the given floating point type, b^{1-p}

FLT_EPSILON	**1E-5**
DBL_EPSILON	**1E-9**
LDBL_EPSILON	**1E-9**

— minimum normalized positive floating-point number, $b^{e_{\min}-1}$

FLT_MIN	**1E-37**
DBL_MIN	**1E-37**
LDBL_MIN	**1E-37**

Examples

[9]

1. The following describes an artificial floating-point representation that meets the minimum requirements of this International Standard, and the appropriate values in a **<float.h>** header for type **float**:

$$x = s \times 16^e \times \sum_{k=1}^{6} f_k \times 16^{-k}\,, \quad -31 \le e \le +32$$

[10]

FLT_RADIX	**16**
FLT_MANT_DIG	**6**
FLT_EPSILON	**9.53674316E-07F**
FLT_DIG	**6**
FLT_MIN_EXP	**-31**
FLT_MIN	**2.93873588E-39F**
FLT_MIN_10_EXP	**-38**
FLT_MAX_EXP	**+32**
FLT_MAX	**3.40282347E+38F**
FLT_MAX_10_EXP	**+38**

2. The following describes floating-point representations that also meet the requirements for single-precision and double-precision normalized numbers in ANSI/IEEE 754-1985,[14] and the appropriate values in a **`<float.h>`** header for types **`float`** and **`double`**:

$$x_f = s \times 2^e \times \sum_{k=1}^{24} f_k \times 2^{-k}, \quad -125 \le e \le +128$$

$$x_d = s \times 2^e \times \sum_{k=1}^{53} f_k \times 2^{-k}, \quad -1021 \le e \le +1024$$

[11]

14. The floating-point model in that standard sums powers of *b* from zero, so the values of the exponent limits are one less than shown here.

```
FLT_RADIX                        2
FLT_MANT_DIG                    24
FLT_EPSILON        1.19209290E-07F
FLT_DIG                          6
FLT_MIN_EXP                   -125
FLT_MIN            1.17549435E-38F
FLT_MIN_10_EXP                 -37
FLT_MAX_EXP                   +128
FLT_MAX            3.40282347E+38F
FLT_MAX_10_EXP                 +38
DBL_MANT_DIG                    53
DBL_EPSILON 2.2204460492503131E-16
DBL_DIG                         15
DBL_MIN_EXP                  -1021
DBL_MIN    2.2250738585072014E-308
DBL_MIN_10_EXP                -307
DBL_MAX_EXP                  +1024
DBL_MAX    1.7976931348623157E+308
DBL_MAX_10_EXP                +308
```

Forward references: conditional inclusion (6.8.1).

6. Language

[1] In the syntax notation used in the language clause (clause 6), syntactic categories (nonterminals) are indicated by *italic* type, and literal words and character set members (terminals) by **bold** type. A colon (*:*) following a nonterminal introduces its definition. Alternative definitions are listed on separate lines, except when prefaced by the words ‘‘one of.’’ An optional symbol is indicated by the subscript ‘‘opt,’’ so that

{ *expression*$_{opt}$ **}**

indicates an optional expression enclosed in braces.

6.1 Lexical elements

Syntax

[1]

token:
keyword
identifier
constant
string-literal
operator
punctuator

preprocessing-token:
header-name
identifier
pp-number
character-constant
string-literal
operator
punctuator
each non-white-space character that cannot be one of the above

Constraints

[2] Each preprocessing token that is converted to a token shall have the lexical form of a keyword, an identifier, a constant, a string literal, an operator, or a punctuator.

Semantics

[3] A *token* is the minimal lexical element of the language in translation phases 7 and 8. The categories of tokens are: *keywords*, *identifiers*, *constants*, *string literals*, *operators*, and *punctuators*. A *preprocessing token* is the minimal lexical element of the language in translation phases 3 through 6. The categories of preprocessing token are: *header names*, *identifiers*, *preprocessing numbers*, *character constants*, *string literals*, *operators*, *punctuators*, and single non-white-space characters that do not lexically match the other preprocessing token categories. If a **'** or a **"** character matches the last category, the behavior is undefined. Preprocessing tokens can be separated by *white space*; this consists of comments (described later), or *white-space characters* (space, horizontal tab, new-line, vertical tab, and form-feed), or both. As described in 6.8, in certain circumstances during translation phase 4, white space (or the absence thereof) serves as more than preprocessing token separation. White space may appear within a preprocessing token only as part of a header name or between the quotation characters in a character constant or string literal.

[4] If the input stream has been parsed into preprocessing tokens up to a given character, the next preprocessing token is the longest sequence of characters that could constitute a preprocessing token.

[5] A header name preprocessing token is only recognized within a **`#include`** preprocessing directive, and within such a directive, a sequence of characters that could be either a header name or a string literal is recognized as the former. *

Examples

1. The program fragment **`1Ex`** is parsed as a preprocessing number token (one that is not a valid floating or integer constant token), even though a parse as the pair of preprocessing tokens **`1`** and **`Ex`** might produce a valid expression (for example, if **`Ex`** were a macro defined as **`+1`**). Similarly, the program fragment **`1E1`** is parsed as a preprocessing number (one that is a valid floating constant token), whether or not **`E`** is a macro name.

2. The program fragment **`x+++++y`** is parsed as **`x ++ ++ + y`**, which violates a constraint on increment operators, even though the parse **`x ++ + ++ y`** might yield a correct expression.

Forward references: character constants (6.1.3.4), comments (6.1.9), expressions (6.3), floating constants (6.1.3.1), header names (6.1.7), macro replacement (6.8.3), postfix increment and decrement operators (6.3.2.4), prefix increment and decrement operators (6.3.3.1), preprocessing directives (6.8), preprocessing numbers (6.1.8), string literals (6.1.4).

6.1.1 Keywords

Syntax

[1] |

keyword: one of

```
auto      break     case      char
complex   const     continue  default
do        double    else      enum
extern    float     for       goto
if        int       long      register
restrict  return    short     signed
sizeof    static    struct    switch
typedef   union     unsigned  void
volatile  while
```

Semantics

[2] The above tokens (entirely in lowercase) are reserved (in translation phases 7 and 8) for use as keywords, and shall not be used otherwise. The token complex is a keyword in translation units where the header **`<complex.h>`** is included, but not otherwise. If the token is used prior to the first inclusion of the header, the behavior is undefined.

6.1.2 Identifiers

Syntax

[1]

identifier:
nondigit
identifier nondigit
identifier digit

nondigit: one of

```
_ a b c d e f g h i j k l m
  n o p q r s t u v w x y z
  A B C D E F G H I J K L M
  N O P Q R S T U V W X Y Z
```

digit: one of

```
0 1 2 3 4 5 6 7 8 9
```

Description

[2] An identifier is a sequence of nondigit characters (including the underscore `_` and the lowercase and uppercase letters) and digits. The first character shall be a nondigit character.

Constraints

[3] In translation phases 7 and 8, an identifier shall not consist of the same sequence of characters as a keyword.

Semantics

[4] An identifier denotes an object, a function, or one of the following entities that will be described later: a tag or a member of a structure, union, or enumeration; a typedef name; a label name; a macro name; or a macro parameter. A member of an enumeration is called an *enumeration constant*. Macro names and macro parameters are not considered further here, because prior to the semantic phase of program translation any occurrences of macro names in the source file are replaced by the preprocessing token sequences that constitute their macro definitions.

[5] There is no specific limit on the maximum length of an identifier.

[6] When preprocessing tokens are converted to tokens during translation phase 7, if a preprocessing token could be converted to either a keyword or an identifier, it is converted to a keyword. *

Implementation limits

[7] The implementation shall treat at least the first 31 characters of an *internal name* (a macro name or an identifier that does not have external linkage) as significant. Corresponding lowercase and uppercase letters are different. The implementation may further restrict the significance of an *external name* (an identifier that has external linkage) to six characters and may ignore distinctions of alphabetical case for such names.[15] These limitations on identifiers are all implementation-defined.

[8] Any identifiers that differ in a significant character are different identifiers. If two identifiers differ in a nonsignificant character, the behavior is undefined.

Forward references: linkages of identifiers (6.1.2.2), macro replacement (6.8.3).

6.1.2.1 Scopes of identifiers

[1] An identifier is *visible* (i.e., can be used) only within a region of program text called its *scope*. There are four kinds of scopes: function, file, block, and function prototype. (A *function prototype* is a declaration of a function that declares the types of its parameters.)

[2] A label name is the only kind of identifier that has *function scope*. It can be used (in a `goto` statement) anywhere in the function in which it appears, and is declared implicitly by its syntactic appearance (followed by a `:` and a statement). Label names shall be unique within a function.

[3] Every other identifier has scope determined by the placement of its declaration (in a declarator or type specifier). If the declarator or type specifier that declares the identifier appears outside of any block or list of parameters, the identifier has *file scope*, which terminates at the end of the translation unit. If the declarator or type specifier that declares the identifier appears inside a block or within the list of

15. See ‘‘future language directions’’ (6.9.1).

parameter declarations in a function definition, the identifier has *block scope*, which terminates at the **}** that closes the associated block. If the declarator or type specifier that declares the identifier appears within the list of parameter declarations in a function prototype (not part of a function definition), the identifier has *function prototype scope*, which terminates at the end of the function declarator. If an outer declaration of a lexically identical identifier exists in the same name space, it is hidden until the current scope terminates, after which it again becomes visible.

[4] Two identifiers have the same scope if and only if their scopes terminate at the same point.

[5] Structure, union, and enumeration tags have scope that begins just after the appearance of the tag in a type specifier that declares the tag. Each enumeration constant has scope that begins just after the appearance of its defining enumerator in an enumerator list. Any other identifier has scope that begins just after the completion of its declarator.

Forward references: compound statement, or block (6.6.2), declarations (6.5), enumeration specifiers (6.5.2.2), function calls (6.3.2.2), function declarators (including prototypes) (6.5.4.3), function definitions (6.7.1), the **goto** statement (6.6.6.1), labeled statements (6.6.1), name spaces of identifiers (6.1.2.3), scope of macro definitions (6.8.3.5), source file inclusion (6.8.2), tags (6.5.2.3), type specifiers (6.5.2).

6.1.2.2 Linkages of identifiers

[1] An identifier declared in different scopes or in the same scope more than once can be made to refer to the same object or function by a process called *linkage*. There are three kinds of linkage: external, internal, and none.

[2] In the set of translation units and libraries that constitutes an entire program, each instance of a particular identifier with *external linkage* denotes the same object or function. Within one translation unit, each instance of an identifier with *internal linkage* denotes the same object or function. Identifiers with *no linkage* denote unique entities.

[3] If the declaration of a file scope identifier for an object or a function contains the storage-class specifier **static**, the identifier has internal linkage.[16]

[4] For an identifier declared with the storage-class specifier **extern** in a scope in which a prior declaration of that identifier is visible,[17] if the prior declaration specifies internal or external linkage, the linkage of the identifier at the later declaration becomes the linkage specified at the prior declaration. If no prior declaration is visible, or if the prior declaration specifies no linkage, then the identifier has external *

16. A function declaration can contain the storage-class specifier **static** only if it is at file scope; see 6.5.1.

17. As specified in 6.1.2.1, the later declaration might hide the prior declaration.

linkage.

[5] If the declaration of an identifier for a function has no storage-class specifier, its linkage is determined exactly as if it were declared with the storage-class specifier **`extern`**. If the declaration of an identifier for an object has file scope and no storage-class specifier, its linkage is external.

[6] The following identifiers have no linkage: an identifier declared to be anything other than an object or a function; an identifier declared to be a function parameter; a block scope identifier for an object declared without the storage-class specifier **`extern`**.

[7] If, within a translation unit, the same identifier appears with both internal and external linkage, the behavior is undefined.

Forward references: compound statement, or block (6.6.2), declarations (6.5), expressions (6.3), external definitions (6.7).

6.1.2.3 Name spaces of identifiers

[1] If more than one declaration of a particular identifier is visible at any point in a translation unit, the syntactic context disambiguates uses that refer to different entities. Thus, there are separate *name spaces* for various categories of identifiers, as follows:

— *label names* (disambiguated by the syntax of the label declaration and use);

— the *tags* of structures, unions, and enumerations (disambiguated by following any[18] of the keywords **`struct`**, **`union`**, or **`enum`**);

— the *members* of structures or unions; each structure or union has a separate name space for its members (disambiguated by the type of the expression used to access the member via the **`.`** or **`->`** operator);

— all other identifiers, called *ordinary identifiers* (declared in ordinary declarators or as enumeration constants).

Forward references: enumeration specifiers (6.5.2.2), labeled statements (6.6.1), structure and union specifiers (6.5.2.1), structure and union members (6.3.2.3), tags (6.5.2.3).

6.1.2.4 Storage durations of objects

[1] An object has a *storage duration* that determines its lifetime. There are three storage durations: static, automatic, and allocated. Allocated storage is described in 7.12.3.

[2] An object whose identifier is declared with external or internal linkage, or with the storage-class specifier **`static`** has *static storage duration*. For such an object,

18. There is only one name space for tags even though three are possible.

storage is reserved and its stored value is initialized only once, prior to program startup. The object exists and retains its last-stored value throughout the execution of the entire program.[19]

[3] An object whose identifier is declared with no linkage and without the storage-class specifier **`static`** has *automatic storage duration*. Storage is guaranteed to be reserved for a new instance of such an object on each normal entry into the block with which it is associated, or on a jump from outside the block to a labeled statement in the block or in an enclosed block. If an initialization is specified for the value stored in the object, it is performed on each normal entry, but not if the block is entered by a jump to a labeled statement. Storage for the object is no longer guaranteed to be reserved when execution of the block ends in any way. (Entering an enclosed block suspends but does not end execution of the enclosing block. Calling a function suspends but does not end execution of the block containing the call.) The value of a pointer that referred to an object with automatic storage duration that is no longer guaranteed to be reserved is indeterminate.

Forward references: compound statement, or block (6.6.2), function calls (6.3.2.2), initialization (6.5.7).

6.1.2.5 Types

[1] The meaning of a value stored in an object or returned by a function is determined by the *type* of the expression used to access it. (An identifier declared to be an object is the simplest such expression; the type is specified in the declaration of the identifier.) Types are partitioned into *object types* (types that describe objects), *function types* (types that describe functions), and *incomplete types* (types that describe objects but lack information needed to determine their sizes).

[2] An object declared as type **`char`** is large enough to store any member of the basic execution character set. If a member of the required source character set enumerated in 5.2.1 is stored in a **`char`** object, its value is guaranteed to be positive. If other quantities are stored in a **`char`** object, the behavior is implementation-defined: the values are treated as either signed or nonnegative integers.

[3] There are five *signed integer types*, designated as **`signed char`**, **`short int`**, **`int`**, **`long int`**. and **`long long int`**. (The signed integer and other types may be designated in several additional ways, as described in 6.5.2.)

[4] An object declared as type **`signed char`** occupies the same amount of storage as a ‘‘plain’’ **`char`** object. A ‘‘plain’’ **`int`** object has the natural size suggested by the architecture of the execution environment (large enough to contain any value in the range **`INT_MIN`** to **`INT_MAX`** as defined in the header **`<limits.h>`**). In the list of signed integer types above, the range of values of each type is a subrange of the

19. In the case of a volatile object, the last store may not be explicit in the program.

values of the next type in the list.

[5] For each of the signed integer types, there is a corresponding (but different) *unsigned integer type* (designated with the keyword **`unsigned`**) that uses the same amount of storage (including sign information) and has the same alignment requirements. The range of nonnegative values of a signed integer type is a subrange of the corresponding unsigned integer type, and the representation of the same value in each type is the same.[20] A computation involving unsigned operands can never overflow, because a result that cannot be represented by the resulting unsigned integer type is reduced modulo the number that is one greater than the largest value that can be represented by the resulting unsigned integer type.

[6] There are three *real floating types*, designated as **`float`**, **`double`**, and **`long double`**. The set of values of the type **`float`** is a subset of the set of values of the type **`double`**; the set of values of the type **`double`** is a subset of the set of values of the type **`long double`**.

[7] There are three *complex types*, designated as **`float complex`**, **`double complex`**, and **`long double complex`**.[21] The real floating and complex types are collectively called the *floating types*.

[8] For each floating type there is a *corresponding real type*, which is always a real floating type. For real floating types, it is the same type. For complex types, it is the type given by deleting the keyword **`complex`** from the type name.

[9] Each complex type has the same representation and alignment requirements as a structured type containing exactly two elements of the corresponding real type; the first element is equal to the real part, and the second element to the imaginary part, of the complex number.

[10] The type **`char`**, the signed and unsigned integer types, and the floating types are collectively called the *basic types*. Even if the implementation defines two or more basic types to have the same representation, they are nevertheless different types.

[11] The three types **`char`**, **`signed char`**, and **`unsigned char`** are collectively called the *character types*.

[12] An *enumeration* comprises a set of named integer constant values. Each distinct enumeration constitutes a different *enumerated type*.

[13] The **`void`** type comprises an empty set of values; it is an incomplete type that cannot be completed.

---

20. The same representation and alignment requirements are meant to imply interchangeability as arguments to functions, return values from functions, and members of unions.

21. Annex Y specifies pure imaginary types, for implementations supporting the infinite, NaN, and signed-zero values in IEC 559.

[14] Any number of *derived types* can be constructed from the object, function, and incomplete types, as follows:

— An *array type* describes a contiguously allocated nonempty set of objects with a particular member object type, called the *element type*.[22] Array types are characterized by their element type and by the number of elements in the array. An array type is said to be derived from its element type, and if its element type is *T*, the array type is sometimes called ‘‘array of *T*.’’ The construction of an array type from an element type is called ‘‘array type derivation.’’

— A *structure type* describes a sequentially allocated nonempty set of member objects, each of which has an optionally specified name and possibly distinct type.

— A *union type* describes an overlapping nonempty set of member objects, each of which has an optionally specified name and possibly distinct type.

— A *function type* describes a function with specified return type. A function type is characterized by its return type and the number and types of its parameters. A function type is said to be derived from its return type, and if its return type is *T*, the function type is sometimes called ‘‘function returning *T*.’’ The construction of a function type from a return type is called ‘‘function type derivation.’’

— A *pointer type* may be derived from a function type, an object type, or an incomplete type, called the *referenced type*. A pointer type describes an object whose value provides a reference to an entity of the referenced type. A pointer type derived from the referenced type *T* is sometimes called ‘‘pointer to *T*.’’ The construction of a pointer type from a referenced type is called ‘‘pointer type derivation.’’

[15] These methods of constructing derived types can be applied recursively.

[16] The type **`char`**, the signed and unsigned integer types, and the enumerated types are collectively called *integral types*. The representations of integral types shall define values by use of a pure binary numeration system.[23] The representations of floating types are unspecified.

[17] Integral and floating types are collectively called *real types*. Arithmetic types and pointer types are collectively called *scalar types*. Array and structure types are collectively called *aggregate types*.[24]

22. Since object types do not include incomplete types, an array of incomplete type cannot be constructed.

23. A positional representation for integers that uses the binary digits 0 and 1, in which the values represented by successive bits are additive, begin with 1, and are multiplied by successive integral powers of 2, except perhaps the bit with the highest position. (Adapted from the *American National Dictionary for Information Processing Systems*.)

24. Note that aggregate type does not include union type because an object with union type can only contain one member at a time.

[18] Each arithmetic type belongs to one type-domain. The real type-domain comprises the real types. The complex type-domain comprises the complex types.

[19] An array type of unknown size is an incomplete type. It is completed, for an identifier of that type, by specifying the size in a later declaration (with internal or external linkage). A structure or union type of unknown content (as described in 6.5.2.3) is an incomplete type. It is completed, for all declarations of that type, by declaring the same structure or union tag with its defining content later in the same scope.

[20] Array, function, and pointer types are collectively called *derived declarator types*. A *declarator type derivation* from a type *T* is the construction of a derived declarator type from *T* by the application of an array-type, a function-type, or a pointer-type derivation to *T*.

[21] A type is characterized by its *type category*, which is either the outermost derivation of a derived type (as noted above in the construction of derived types), or the type itself if the type consists of no derived types.

[22] Any type so far mentioned is an *unqualified type*. Each unqualified type has three corresponding *qualified versions* of its type:[25] a *const-qualified* version, a *volatile-qualified* version, and a version having both qualifications. The qualified or unqualified versions of a type are distinct types that belong to the same type category and have the same representation and alignment requirements.[20] A derived type is not qualified by the qualifiers (if any) of the type from which it is derived.

[23] A pointer to **`void`** shall have the same representation and alignment requirements as a pointer to a character type. Similarly, pointers to qualified or unqualified versions of compatible types shall have the same representation and alignment requirements.[20] Pointers to other types need not have the same representation or alignment requirements.

Examples

[24]

1. The type designated as ‘‘**`float *`**’’ has type ‘‘pointer to **`float`**.’’ Its type category is pointer, not a floating type. The const-qualified version of this type is designated as ‘‘**`float * const`**’’ whereas the type designated as ‘‘**`const float *`**’’ is not a qualified type — its type is ‘‘pointer to const-qualified **`float`**’’ and is a pointer to a qualified type.

2. The type designated as ‘‘**`struct tag (*[5])(float)`**’’ has type ‘‘array of pointer to function returning **`struct tag`**.’’ The array has length five and the function has a single parameter of type **`float`**. Its type category is array.

25. See 6.5.3 regarding qualified array and function types.

Forward references: character constants (6.1.3.4), compatible type and composite type (6.1.2.6), declarations (6.5), tags (6.5.2.3), type qualifiers (6.5.3).

6.1.2.6 Compatible type and composite type

[1] Two types have *compatible type* if their types are the same. Additional rules for determining whether two types are compatible are described in 6.5.2 for type specifiers, in 6.5.3 for type qualifiers, and in 6.5.4 for declarators.[26] Moreover, two structure, union, or enumeration types declared in separate translation units are compatible if their tags and members satisfy the following requirements. If one is declared with a tag, the other shall be declared with the same tag. If both are complete types, then the following additional requirements apply. There shall be a one-to-one correspondence between their members such that each pair of corresponding members are declared with compatible types, and such that if one member of a corresponding pair is declared with a name, the other member is declared with the same name. For two structures, corresponding members shall be declared in the same order. For two structures or unions, corresponding bit-fields shall have the same widths. For two enumerations, corresponding members shall have the same values.

[2] All declarations that refer to the same object or function shall have compatible type; otherwise, the behavior is undefined.

[3] A *composite type* can be constructed from two types that are compatible; it is a type that is compatible with both of the two types and satisfies the following conditions:

— If one type is an array of known size, the composite type is an array of that size.

— If only one type is a function type with a parameter type list (a function prototype), the composite type is a function prototype with the parameter type list.

— If both types are function types with parameter type lists, the type of each parameter in the composite parameter type list is the composite type of the corresponding parameters.

[4] These rules apply recursively to the types from which the two types are derived.

[5] For an identifier with internal or external linkage declared in a scope in which a prior declaration of that identifier is visible,[27] if the prior declaration specifies internal or external linkage, the type of the identifier at the later declaration becomes the composite type. *

Example

26. Two types need not be identical to be compatible.

27. As specified in 6.1.2.1, the later declaration might hide the prior declaration.

[6] Given the following two file scope declarations:

```
int f(int (*)(), double (*)[3]);
int f(int (*)(char *), double (*)[]);
```

The resulting composite type for the function is:

```
int f(int (*)(char *), double (*)[3]);
```

Forward references: declarators (6.5.4), enumeration specifiers (6.5.2.2), structure and union specifiers (6.5.2.1), type definitions (6.5.6), type qualifiers (6.5.3), type specifiers (6.5.2).

6.1.3 Constants

Syntax

[1]

constant:
    floating-constant
    integer-constant
    enumeration-constant
    character-constant

Constraints

[2] The value of a constant shall be in the range of representable values for its type.

Semantics

[3] Each constant has a type, determined by its form and value, as detailed later.

6.1.3.1 Floating constants

Syntax

[1]

floating-constant:
    decimal-floating-constant
    hexadecimal-floating-constant

decimal-floating-constant:
    fractional-constant exponent-part$_{opt}$ *floating-suffix*$_{opt}$
    digit-sequence exponent-part floating-suffix$_{opt}$

hexadecimal-floating-constant:
  `0x` *hexadecimal-fractional-constant*
    binary-exponent-part floating-suffix$_{opt}$
  `0X` *hexadecimal-fractional-constant*
    binary-exponent-part floating-suffix$_{opt}$
  `0x` *hexadecimal-digit-sequence*
    binary-exponent-part floating-suffix$_{opt}$
  `0X` *hexadecimal-digit-sequence*
    binary-exponent-part floating-suffix$_{opt}$

fractional-constant:
  digit-sequence$_{opt}$ **`.`** *digit-sequence*
  digit-sequence **`.`**

exponent-part:
  `e` *sign*$_{opt}$ *digit-sequence*
  `E` *sign*$_{opt}$ *digit-sequence*

sign: one of
  `+ -`

digit-sequence:
  digit
  digit-sequence digit

hexadecimal-fractional-constant:
  hexadecimal-digit-sequence$_{opt}$ **`.`**
  hexadecimal-digit-sequence
  hexadecimal-digit-sequence **`.`**

binary-exponent-part:
  `p` *sign*$_{opt}$ *digit-sequence*
  `P` *sign*$_{opt}$ *digit-sequence*

hexadecimal-digit-sequence:
  hexadecimal-digit
  hexadecimal-digit-sequence hexadecimal-digit

hexadecimal-digit: one of
  `0 1 2 3 4 5 6 7 8 9`
  `a b c d e f`
  `A B C D E F`

floating-suffix: one of
  `f l F L`

Description

[2] A floating constant has a *significand part* that may be followed by an *exponent part* and a suffix that specifies its type. The components of the significand part may include a digit sequence representing the whole-number part, followed by a period (`.`), followed by a digit sequence representing the fraction part. The components of the exponent part are an **`e`**, **`E`**, **`p`**, or **`P`** followed by an exponent consisting of an optionally signed digit sequence. Either the whole-number part or the fraction part shall be present; for decimal floating constants, either the period or the exponent part shall be present.

Semantics

[3] The significand part is interpreted as a (decimal or hexadecimal) rational number; the digit sequence in the exponent part is interpreted as a decimal integer. For decimal floating constants, the exponent indicates the power of 10 by which the significand part is to be scaled. For hexadecimal floating constants, the exponent indicates the power of 2 by which the significand part is to be scaled. For decimal floating constants, and also for hexadecimal floating constants when **`FLT_RADIX`** is not a power of 2, if the scaled value is in the range of representable values (for its type) the result is either the nearest representable value, or the larger or smaller representable value immediately adjacent to the nearest representable value, chosen in an implementation-defined manner. For hexadecimal floating constants, if **`FLT_RADIX`** is a power of 2 and the scaled value is in the range of representable values (for its type), then the result of a hexadecimal floating constant is correctly rounded.

[4] An unsuffixed floating constant has type **`double`**. If suffixed by the letter **`f`** or **`F`**, it has type **`float`**. If suffixed by the letter **`l`** or **`L`**, it has type **`long double`**.

Recommended practice

[5] The implementation emits a non-fatal diagnostic if a hexadecimal constant cannot be represented exactly in its evaluation format.

6.1.3.2 Integer constants

Syntax

[1]

integer-constant:
  decimal-constant integer-suffix$_{opt}$
  octal-constant integer-suffix$_{opt}$
  hexadecimal-constant integer-suffix$_{opt}$

decimal-constant:
  nonzero-digit
  decimal-constant digit

octal-constant:
  `0`
  octal-constant octal-digit

nonzero-digit: one of *
`1 2 3 4 5 6 7 8 9`

octal-digit: one of
`0 1 2 3 4 5 6 7`

integer-suffix: *
unsigned-suffix long-suffix$_{opt}$
long-suffix unsigned-suffix$_{opt}$

unsigned-suffix: one of
`u U`

long-suffix: one of
`l L`

Description

[2] An integer constant begins with a digit, but has no period or exponent part. It may have a prefix that specifies its base and a suffix that specifies its type.

[3] A decimal constant begins with a nonzero digit and consists of a sequence of decimal digits. An octal constant consists of the prefix **`0`** optionally followed by a sequence of the digits **`0`** through **`7`** only. A hexadecimal constant consists of the prefix **`0x`** or **`0X`** followed by a sequence of the decimal digits and the letters **`a`** (or **`A`**) through **`f`** (or **`F`**) with values 10 through 15 respectively.

Semantics

[4] The value of a decimal constant is computed base 10; that of an octal constant, base 8; that of a hexadecimal constant, base 16. The lexically first digit is the most significant.

[5] The type of an integer constant is the first of the corresponding list in which its value can be represented. Unsuffixed decimal: **`int`**, **`long int`**, **`unsigned long int`**, **`long long int`**, **`unsigned long long int`**; unsuffixed octal or hexadecimal: **`int`**, **`unsigned int`**, **`long int`**, **`unsigned long int`**, **`long long int`**, **`unsigned long long int`**; suffixed by the letter **`u`** or **`U`**: **`unsigned int`**, **`unsigned long int`**, **`unsigned long long int`**; suffixed by the letter **`l`** or **`L`**: **`long int`**, **`unsigned long int`**, **`long long int`**, **`unsigned long long int`**; suffixed by both the letters **`u`** or **`U`** and **`l`** or **`L`**: **`unsigned long int`**, **`unsigned long long int`**; suffixed by **`ll`** or **`LL`**: **`long long int`**, **`unsigned long long int`**; suffixed by both **`u`** or **`U`** and **`ll`** or **`LL`**: **`unsigned long long int`**. |

6.1.3.3 Enumeration constants

Syntax

[1]

enumeration-constant:
    identifier

Semantics

[2] An identifier declared as an enumeration constant has type **`int`**.

Forward references: enumeration specifiers (6.5.2.2).

6.1.3.4 Character constants

Syntax

[1]

character-constant:
    `'`*c-char-sequence***`'`**
    `L'`*c-char-sequence***`'`**

c-char-sequence:
    c-char
    c-char-sequence c-char

c-char:
    any member of the source character set except
        the single-quote **`'`**, backslash **`\`**, or new-line character
    escape-sequence

escape-sequence:
    simple-escape-sequence
    octal-escape-sequence
    hexadecimal-escape-sequence

simple-escape-sequence: one of
    `\'  \"  \?  \\`
    `\a  \b  \f  \n  \r  \t  \v`

octal-escape-sequence:
    `\` *octal-digit*
    `\` *octal-digit octal-digit*
    `\` *octal-digit octal-digit octal-digit*

hexadecimal-escape-sequence:
    `\x` *hexadecimal-digit*
    hexadecimal-escape-sequence hexadecimal-digit

Description

[2] An integer character constant is a sequence of one or more multibyte characters enclosed in single-quotes, as in **`'x'`** or **`'ab'`**. A wide character constant is the same, except prefixed by the letter **`L`**. With a few exceptions detailed later, the elements of the sequence are any members of the source character set; they are mapped in an implementation-defined manner to members of the execution character set.

[3] The single-quote **`'`**, the double-quote **`"`**, the question-mark **`?`**, the backslash **`\`**, and arbitrary integral values, are representable according to the following table of escape sequences:

single-quote **`'`**	**`\'`**
double-quote **`"`**	**`\"`**
question-mark **`?`**	**`\?`**
backslash **`\`**	**`\\`**
octal integer	**`\`***octal digits*
hexadecimal integer	**`\x`***hexadecimal digits*

[4] The double-quote **`"`** and question-mark **`?`** are representable either by themselves or by the escape sequences **`\"`** and **`\?`**, respectively, but the single-quote **`'`** and the backslash **`\`** shall be represented, respectively, by the escape sequences **`\'`** and **`\\`**.

[5] The octal digits that follow the backslash in an octal escape sequence are taken to be part of the construction of a single character for an integer character constant or of a single wide character for a wide character constant. The numerical value of the octal integer so formed specifies the value of the desired character or wide character.

[6] The hexadecimal digits that follow the backslash and the letter **`x`** in a hexadecimal escape sequence are taken to be part of the construction of a single character for an integer character constant or of a single wide character for a wide character constant. The numerical value of the hexadecimal integer so formed specifies the value of the desired character or wide character.

[7] Each octal or hexadecimal escape sequence is the longest sequence of characters that can constitute the escape sequence.

[8] In addition, certain nongraphic characters are representable by escape sequences consisting of the backslash **`\`** followed by a lowercase letter: **`\a`**, **`\b`**, **`\f`**, **`\n`**, **`\r`**, **`\t`**, and **`\v`**.[28] If any other escape sequence is encountered, the behavior is undefined.[29]

Constraints

[9] The value of an octal or hexadecimal escape sequence shall be in the range of representable values for the type **`unsigned char`** for an integer character constant, or the unsigned type corresponding to **`wchar_t`** for a wide character constant.

---

28. The semantics of these characters were discussed in 5.2.2.

29. See ''future language directions'' (6.9.2).

Semantics

[10] An integer character constant has type **`int`**. The value of an integer character constant containing a single character that maps into a member of the basic execution character set is the numerical value of the representation of the mapped character interpreted as an integer. The value of an integer character constant containing more than one character, or containing a character or escape sequence not represented in the basic execution character set, is implementation-defined. If an integer character constant contains a single character or escape sequence, its value is the one that results when an object with type **`char`** whose value is that of the single character or escape sequence is converted to type **`int`**.

[11] A wide character constant has type **`wchar_t`**, an integral type defined in the **`<stddef.h>`** header. The value of a wide character constant containing a single multibyte character that maps into a member of the extended execution character set is the *wide character* (code) corresponding to that multibyte character, as defined by the **`mbtowc`** function, with an implementation-defined current locale. The value of a wide character constant containing more than one multibyte character, or containing a multibyte character or escape sequence not represented in the extended execution character set, is implementation-defined.

Examples

[12]

1. The construction **`'\0'`** is commonly used to represent the null character.

2. Consider implementations that use two's-complement representation for integers and eight bits for objects that have type **`char`**. In an implementation in which type **`char`** has the same range of values as **`signed char`**, the integer character constant **`'\xFF'`** has the value -1; if type **`char`** has the same range of values as **`unsigned char`**, the character constant **`'\xFF'`** has the value $+255$.

3. Even if eight bits are used for objects that have type **`char`**, the construction **`'\x123'`** specifies an integer character constant containing only one character. (The value of this single-character integer character constant is implementation-defined and violates the above constraint.) To specify an integer character constant containing the two characters whose values are **`0x12`** and **`'3'`**, the construction **`'\0223'`** may be used, since a hexadecimal escape sequence is terminated only by a nonhexadecimal character. (The value of this two-character integer character constant is implementation-defined also.)

4. Even if 12 or more bits are used for objects that have type **`wchar_t`**, the construction **`L'\1234'`** specifies the implementation-defined value that results from the combination of the values **`0123`** and **`'4'`**.

Forward references: characters and integers (6.2.1.1), common definitions **`<stddef.h>`** (7.1.6), the **`mbtowc`** function (7.12.7.2).

6.1.4 String literals

Syntax

[1]

string-literal:
    "*s-char-sequence*$_{opt}$**"**
    L"*s-char-sequence*$_{opt}$**"**

s-char-sequence:
    s-char
    s-char-sequence s-char

s-char:
    any member of the source character set except
        the double-quote **"**, backslash ****, or new-line character
    escape-sequence

Description

[2] A character string literal is a sequence of zero or more multibyte characters enclosed in double-quotes, as in **"xyz"**. A wide string literal is the same, except prefixed by the letter **L**.

[3] The same considerations apply to each element of the sequence in a character string literal or a wide string literal as if it were in an integer character constant or a wide character constant, except that the single-quote **'** is representable either by itself or by the escape sequence **\\'**, but the double-quote **"** shall be represented by the escape sequence **\\"**.

Semantics

[4] In translation phase 6, the multibyte character sequences specified by any sequence of adjacent character string literal tokens, or adjacent wide string literal tokens, are concatenated into a single multibyte character sequence. If a character string literal token is adjacent to a wide string literal token, the behavior is undefined.

[5] In translation phase 7, a byte or code of value zero is appended to each multibyte character sequence that results from a string literal or literals.[30] The multibyte character sequence is then used to initialize an array of static storage duration and length just sufficient to contain the sequence. For character string literals, the array elements have type **char**, and are initialized with the individual bytes of the multibyte character sequence; for wide string literals, the array elements have type **wchar_t**, and are initialized with the sequence of wide characters corresponding to the multibyte

---

30. A character string literal need not be a string (see 7.1.1), because a null character may be embedded in it by a **\0** escape sequence.

character sequence.

[6] These arrays need not be distinct provided their elements have the appropriate values. If the program attempts to modify such an array, the behavior is undefined.

Example

[7] This pair of adjacent character string literals

```
"\x12" "3"
```

produces a single character string literal containing the two characters whose values are `\x12` and `'3'`, because escape sequences are converted into single members of the execution character set just prior to adjacent string literal concatenation.

Forward references: common definitions `<stddef.h>` (7.1.6).

6.1.5 Operators

Syntax

[1]

operator: one of

```
    [  ]  (  )  .  ->
    ++  --  &  *  +  -  ~  !  sizeof
    /  %  <<  >>  <  >  <=  >=  ==  !=  ^  |  &&  ||
    ?  :
    =  *=  /=  %=  +=  -=  <<=  >>=  &=  ^=  |=
    ,  #  ##  <:  :>  %:  %:%:
```

Constraints

[2] The operators `[ ]`, `( )`, and `? :` (independent of spelling) shall occur in pairs, possibly separated by expressions. The operators `#` and `##` (also spelled `%:` and `%:%:`, respectively) shall occur in macro-defining preprocessing directives only.

Semantics

[3] An operator specifies an operation to be performed (an *evaluation*) that yields a value, or yields a designator, or produces a side effect, or a combination thereof. An *operand* is an entity on which an operator acts.

[4] In all aspects of the language, these six tokens

```
<:  :>  <%  %>  %:  %:%:
```

[5] behave, respectively, the same as these six tokens

```
[  ]  {  }  #  ##
```

[6] except for their spelling.[31]

Forward references: expressions (6.3), macro replacement (6.8.3).

6.1.6 Punctuators

Syntax

[1]

punctuator: one of
`[ ] ( ) { } * , : = ; ... #`
`<: :> <% %> %:`

Constraints

[2] The punctuators `[ ]`, `( )`, and `{ }` (independent of spelling) shall occur (after translation phase 4) in pairs, possibly separated by expressions, declarations, or statements. The punctuator `#` (also spelled `%:`) shall occur in preprocessing directives only.

Semantics

[3] A punctuator is a symbol that has independent syntactic and semantic significance but does not specify an operation to be performed that yields a value. Depending on context, the same symbol may also represent an operator or part of an operator.

Forward references: expressions (6.3), declarations (6.5), preprocessing directives (6.8), statements (6.6).

6.1.7 Header names

Syntax

[1]

header-name:
<*h-char-sequence*>
"*q-char-sequence*"

h-char-sequence:
h-char
h-char-sequence h-char

h-char:
any member of the source character set except
the new-line character and `>`

31. Thus `[` and `<:` behave differently when ‘‘stringized’’ (see subclause 6.8.3.2), but can otherwise be freely interchanged.

q-char-sequence:
q-char
q-char-sequence q-char

q-char:
any member of the source character set except
the new-line character and `"`

Semantics

[2] The sequences in both forms of header names are mapped in an implementation-defined manner to headers or external source file names as specified in 6.8.2.

[3] If the characters `'`, `\`, `"`, or `/*` occur in the sequence between the `<` and `>` delimiters, the behavior is undefined. Similarly, if the characters `'`, `\`, or `/*` occur in the sequence between the `"` delimiters, the behavior is undefined.[32] A header name preprocessing token is recognized only within a `#include` preprocessing directive. *

Example

[4] The following sequence of characters:

```
0x3<1/a.h>1e2
#include <1/a.h>
#define const.member@$
```

forms the following sequence of preprocessing tokens (with each individual preprocessing token delimited by a { on the left and a } on the right).

```
{0x3}{<}{1}{/}{a}{.}{h}{>}{1e2}
{#}{include} {<1/a.h>}
{#}{define} {const}{.}{member}{@}{$}
```

Forward references: source file inclusion (6.8.2).

6.1.8 Preprocessing numbers

Syntax

[1]

32. Thus, sequences of characters that resemble escape sequences cause undefined behavior.

pp-number:
  digit
  . *digit*
  pp-number digit
  pp-number nondigit
  pp-number **e** *sign*
  pp-number **E** *sign*
  pp-number **p** *sign*
  pp-number **P** *sign*
  pp-number **.**

Description

[2] A preprocessing number begins with a digit optionally preceded by a period (**.**) and may be followed by letters, underscores, digits, periods, and **e+**, **e-**, **E+**, or **E-** character sequences.

[3] Preprocessing number tokens lexically include all floating and integer constant tokens.

Semantics

[4] A preprocessing number does not have type or a value; it acquires both after a successful conversion (as part of translation phase 7) to a floating constant token or an integer constant token.

6.1.9 Comments

[1] Except within a character constant, a string literal, or a comment, the characters **/*** introduce a comment. The contents of a comment are examined only to identify multibyte characters and to find the characters ***/** that terminate it.[33]

33. Thus, comments do not nest.

6.2 Conversions

[1] Several operators convert operand values from one type to another automatically. This subclause specifies the result required from such an *implicit conversion*, as well as those that result from a cast operation (an *explicit conversion*). The list in 6.2.1.5 summarizes the conversions performed by most ordinary operators; it is supplemented as required by the discussion of each operator in 6.3.

[2] Conversion of an operand value to a compatible type causes no change to the value or the representation.

Forward references: cast operators (6.3.4).

6.2.1 Arithmetic operands

6.2.1.1 Characters and integers

[1] A **`char`**, a **`short int`**, or an **`int`** bit-field, or their signed or unsigned varieties, or an enumeration type, may be used in an expression wherever an **`int`** or **`unsigned int`** may be used. If an **`int`** can represent all values of the original type, the value is converted to an **`int`**; otherwise, it is converted to an **`unsigned int`**. These are called the *integral promotions*.[34] All other arithmetic types are unchanged by the integral promotions.

[2] The integral promotions preserve value including sign. As discussed earlier, whether a ''plain'' **`char`** is treated as signed is implementation-defined.

Forward references: enumeration specifiers (6.5.2.2), structure and union specifiers (6.5.2.1).

6.2.1.2 Signed and unsigned integers

[1] When a value with integral type is converted to another integral type, if the value can be represented by the new type, its value is unchanged.

[2] When a signed integer is converted to an unsigned integer with equal or greater size, if the value of the signed integer is nonnegative, its value is unchanged. Otherwise: if the unsigned integer has greater size, the signed integer is first promoted to the signed integer corresponding to the unsigned integer; the value is converted to unsigned by adding to it one greater than the largest number that can be represented in the unsigned integer type.[35]

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34. The integral promotions are applied only as part of the usual arithmetic conversions, to certain argument expressions, to the operands of the unary **`+`**, **`-`**, and **`~`** operators, and to both operands of the shift operators, as specified by their respective subclauses.

35. In a two's-complement representation, there is no actual change in the bit pattern except filling the high-order bits with copies of the sign bit if the unsigned integer has greater size.

[3] When a value with integral type is demoted to an unsigned integer with smaller size, the result is the nonnegative remainder on division by the number one greater than the largest unsigned number that can be represented in the type with smaller size. When a value with integral type is demoted to a signed integer with smaller size, or an unsigned integer is converted to its corresponding signed integer, if the value cannot be represented the result is implementation-defined.

6.2.1.3 Real floating and integral

[1] When a value of real floating type is converted to integral type, the fractional part is discarded. If the value of the integral part cannot be represented by the integral type, the behavior is undefined.[36]

[2] When a value of integral type is converted to real floating type, if the value being converted is in the range of values that can be represented but cannot be represented exactly, the result is either the nearest higher or nearest lower value, chosen in an implementation-defined manner.

6.2.1.4 Real floating types

[1] When a **`float`** is promoted to **`double`** or **`long double`**, or a **`double`** is promoted to **`long double`**, its value is unchanged.

[2] When a **`double`** is demoted to **`float`** or a **`long double`** to **`double`** or **`float`**, if the value being converted is outside the range of values that can be represented, the behavior is undefined. If the value being converted is in the range of values that can be represented but cannot be represented exactly, the result is either the nearest higher or nearest lower value, chosen in an implementation-defined manner.

6.2.1.5 Complex types

[1] When a value of complex type is converted to another complex type, both the real and imaginary parts follow the conversion rules for the corresponding real types.

6.2.1.6 Real and complex

[1] When a value of real type is converted to a complex type, the real part of the complex result value is determined by the rules of conversion to the corresponding real type and the imaginary part of the complex result value is a positive zero or an unsigned zero.

[2] When a value of complex type is converted to a real type, the imaginary part of the complex value is discarded and the value of the real part is converted according to the conversion rules for the corresponding real type.

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36. The remaindering operation performed when a value of integral type is converted to unsigned type need not be performed when a value of real floating type is converted to unsigned type. Thus, the range of portable real floating values is (−1,**`U`***type*_**`MAX`**+1).

6.2.1.7 Usual arithmetic conversions

[1] Many binary operators that expect operands of arithmetic type cause conversions and yield result types in a similar way. [**Editor: The following text was to be included, but the wording needs rework.** The purpose is to determine a common real type for the operands and result. For the operands, each operand is converted, without change of type-domain, to a type whose corresponding real type is the common real type. The common real type is also the corresponding real type of the result, whose type-domain is determined by the operator. This pattern is called the usual arithmetic conversions: First, if the corresponding real type of either operand is **`long`**double**`,`** the other operand is converted, without change of type-domain, to a type whose corresponding real type is **`long`**double**`.`** Otherwise, if the corresponding real type of either operand is **`double`**, the other operand is converted, without change of type-domain, to a type whose corresponding real type is **`double`**. Otherwise, if the corresponding real type of either operand is **`float`**, the other operand is converted, without change of type-domain, to a type whose corresponding real type is **`float`**. Footnote the second sentence of the inserted text above with: For example, addition of a double complex and a float entails just the conversion of the float operand to double (and yields a double complex result).] The purpose is to yield a common type, which is also the type of the result. This pattern is called the *usual arithmetic conversions*:

First, if either operand has type **`long double`**, the other operand is converted to **`long double`**.

Otherwise, if either operand has type **`double`**, the other operand is converted to **`double`**.

Otherwise, if either operand has type **`float`**, the other operand is converted to **`float`**.

Otherwise, the integral promotions are performed on both operands. Then the following rules are applied:

If either operand has type **`unsigned long long int`**, the other operand is converted to **`unsigned long long int`**.

Otherwise, if one operand has type **`long long int`** and the other has type **`unsigned long int`**, if a **`long long int`** can represent all values of an **`unsigned long int`**, the operand of type **`unsigned long int`** is converted to **`long long int`**; if a **`long long int`** cannot represent all the values of an **`unsigned long int`**, both operands are converted to **`unsigned long long int`**.

Otherwise, if one operand has type **`long long int`** and the other has type **`unsigned int`**, if a **`long long int`** can represent all values of an **`unsigned int`**, the operand of type **`unsigned int`** is converted to **`long long int`**; if a **`long long int`** cannot represent all the values of an **`unsigned int`**, both operands are converted to **`unsigned long`**

`long int`.

Otherwise, if either operand has type **`long long int`**, the other operand is converted to **`long long int`**.

Otherwise, if either operand has type **`unsigned long int`**, the other operand is converted to **`unsigned long int`**.

Otherwise, if one operand has type **`long int`** and the other has type **`unsigned int`**, if a **`long int`** can represent all values of an **`unsigned int`**, the operand of type **`unsigned int`** is converted to **`long int`**; if a **`long int`** cannot represent all the values of an **`unsigned int`**, both operands are converted to **`unsigned long int`**.

Otherwise, if either operand has type **`long int`**, the other operand is converted to **`long int`**.

Otherwise, if either operand has type **`unsigned int`**, the other operand is converted to **`unsigned int`**.

Otherwise, both operands have type **`int`**.

[2] The values of floating operands and of the results of floating expressions may be represented in greater precision and range than that required by the type; the types are not changed thereby.[37]

6.2.2 Other operands

6.2.2.1 Lvalues and function designators

[1] An *lvalue* is an expression (with an object type or an incomplete type other than **`void`**) that designates an object.[38] When an object is said to have a particular type, the type is specified by the lvalue used to designate the object. A *modifiable lvalue* is an lvalue that does not have array type, does not have an incomplete type, does not have a const-qualified type, and if it is a structure or union, does not have any member (including, recursively, any member or element of all contained aggregates or unions) with a const-qualified type.

[2] Except when it is the operand of the **`sizeof`** operator, the unary **`&`** operator, the **`++`** operator, the **`--`** operator, or the left operand of the **`.`** operator or an assignment operator, an lvalue that does not have array type is converted to the value stored in the

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37. The cast and assignment operators still must perform their specified conversions, as described in 6.2.1.3 and 6.2.1.4.

38. The name ‘‘lvalue’’ comes originally from the assignment expression **`E1 = E2`**, in which the left operand **`E1`** must be a (modifiable) lvalue. It is perhaps better considered as representing an object ‘‘locator value.’’ What is sometimes called ‘‘rvalue’’ is in this International Standard described as the ‘‘value of an expression.’’
An obvious example of an lvalue is an identifier of an object. As a further example, if **`E`** is a unary expression that is a pointer to an object, **`*E`** is an lvalue that designates the object to which **`E`** points.

designated object (and is no longer an lvalue). If the lvalue has qualified type, the value has the unqualified version of the type of the lvalue; otherwise, the value has the type of the lvalue. If the lvalue has an incomplete type and does not have array type, the behavior is undefined.

[3] Except when it is the operand of the **`sizeof`** operator or the unary **`&`** operator, or is a character string literal used to initialize an array of character type, or is a wide string literal used to initialize an array with element type compatible with **`wchar_t`**, an lvalue that has type ‘‘array of *type*’’ is converted to an expression that has type ‘‘pointer to *type*’’ that points to the initial element of the array object and is not an lvalue.

[4] A *function designator* is an expression that has function type. Except when it is the operand of the **`sizeof`** operator[39] or the unary **`&`** operator, a function designator with type ‘‘function returning *type*’’ is converted to an expression that has type ‘‘pointer to function returning *type*.’’

Forward references: address and indirection operators (6.3.3.2), assignment operators (6.3.16), common definitions **`<stddef.h>`** (7.1.6), initialization (6.5.7), postfix increment and decrement operators (6.3.2.4), prefix increment and decrement operators (6.3.3.1), the **`sizeof`** operator (6.3.3.4), structure and union members (6.3.2.3).

6.2.2.2 `void`

[1] The (nonexistent) value of a *void expression* (an expression that has type **`void`**) shall not be used in any way, and implicit or explicit conversions (except to **`void`**) shall not be applied to such an expression. If an expression of any other type occurs in a context where a void expression is required, its value or designator is discarded. (A void expression is evaluated for its side effects.)

6.2.2.3 Pointers

[1] A pointer to **`void`** may be converted to or from a pointer to any incomplete or object type. A pointer to any incomplete or object type may be converted to a pointer to **`void`** and back again; the result shall compare equal to the original pointer.

[2] For any qualifier q, a pointer to a non-q-qualified type may be converted to a pointer to the q-qualified version of the type; the values stored in the original and converted pointers shall compare equal.

[3] An integral constant expression with the value 0, or such an expression cast to type **`void *`**, is called a *null pointer constant*.[40] If a null pointer constant is assigned to or compared for equality to a pointer, the constant is converted to a pointer of that type.

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39. Because this conversion does not occur, the operand of the **`sizeof`** operator remains a function designator and violates the constraint in 6.3.3.4.

40. The macro **`NULL`** is defined in **`<stddef.h>`** as a null pointer constant; see 7.1.6.

Such a pointer, called a *null pointer*, is guaranteed to compare unequal to a pointer to any object or function.

[4] Two null pointers, converted through possibly different sequences of casts to pointer types, shall compare equal.

Forward references: cast operators (6.3.4), equality operators (6.3.9), simple assignment (6.3.16.1).

6.3 Expressions

[1] An *expression* is a sequence of operators and operands that specifies computation of a value, or that designates an object or a function, or that generates side effects, or that performs a combination thereof.

[2] Between the previous and next sequence point an object shall have its stored value modified at most once by the evaluation of an expression. Furthermore, the prior value shall be accessed only to determine the value to be stored.[41]

[3] Except as indicated by the syntax[42] or otherwise specified later (for the function-call operator **()**, **&&**, **||**, **?:**, and comma operators), the order of evaluation of subexpressions and the order in which side effects take place are both unspecified.

[4] Some operators (the unary operator **~**, and the binary operators **<<**, **>>**, **&**, **^**, and **|**, collectively described as *bitwise operators*) shall have operands that have integral type. These operators return values that depend on the internal representations of integers, and thus have implementation-defined aspects for signed types.

[5] If an *exception* occurs during the evaluation of an expression (that is, if the result is not mathematically defined or not in the range of representable values for its type), the behavior is undefined.

[6] An object shall have its stored value accessed only by an lvalue expression that has one of the following types:[43]

— a type compatible with the declared type of the object, *

— a qualified version of a type compatible with the declared type of the object, *

— a type that is the signed or unsigned type corresponding to the declared type of the object,

41. This paragraph renders undefined statement expressions such as

```
i = ++i + 1;
```

while allowing

```
i = i + 1;
```

42. The syntax specifies the precedence of operators in the evaluation of an expression, which is the same as the order of the major subclauses of this subclause, highest precedence first. Thus, for example, the expressions allowed as the operands of the binary **+** operator (6.3.6) shall be those expressions defined in 6.3.1 through 6.3.6. The exceptions are cast expressions (6.3.4) as operands of unary operators (6.3.3), and an operand contained between any of the following pairs of operators: grouping parentheses **()** (6.3.1), subscripting brackets **[]** (6.3.2.1), function-call parentheses **()** (6.3.2.2), and the conditional operator **?:** (6.3.15). |

Within each major subclause, the operators have the same precedence. Left- or right-associativity is indicated in each subclause by the syntax for the expressions discussed therein.

43. The intent of this list is to specify those circumstances in which an object may or may not be aliased.

— a type that is the signed or unsigned type corresponding to a qualified version of the declared type of the object,

— an aggregate or union type that includes one of the aforementioned types among its members (including, recursively, a member of a subaggregate or contained union), or

— a character type.

6.3.1 Primary expressions

Syntax

[1]

primary-expression:
  identifier
  constant
  string-literal
  (*expression* **)**

Semantics

[2] An identifier is a primary expression, provided it has been declared as designating an object (in which case it is an lvalue) or a function (in which case it is a function designator).

[3] A constant is a primary expression. Its type depends on its form and value, as detailed in 6.1.3.

[4] A string literal is a primary expression. It is an lvalue with type as detailed in 6.1.4.

[5] A parenthesized expression is a primary expression. Its type and value are identical to those of the unparenthesized expression. It is an lvalue, a function designator, or a void expression if the unparenthesized expression is, respectively, an lvalue, a function designator, or a void expression.

Forward references: declarations (6.5).

6.3.2 Postfix operators

Syntax

[1]

postfix-expression:
    primary-expression
    postfix-expression **[** *expression* **]**
    postfix-expression **(** *argument-expression-list*$_{opt}$ **)**
    postfix-expression **.** *identifier*
    postfix-expression **->** *identifier*
    postfix-expression **++**
    postfix-expression **--**

argument-expression-list:
    assignment-expression
    argument-expression-list **,** *assignment-expression*

6.3.2.1 Array subscripting

Constraints

[1] One of the expressions shall have type ‘‘pointer to object *type*,’’ the other expression shall have integral type, and the result has type ‘‘*type*.’’

Semantics

[2] A postfix expression followed by an expression in square brackets **[]** is a subscripted designation of an element of an array object. The definition of the subscript operator **[]** is that **E1[E2]** is identical to **(*(E1+(E2)))**. Because of the conversion rules that apply to the binary **+** operator, if **E1** is an array object (equivalently, a pointer to the initial element of an array object) and **E2** is an integer, **E1[E2]** designates the **E2**-th element of **E1** (counting from zero).

[3] Successive subscript operators designate an element of a multidimensional array object. If **E** is an n-dimensional array ($n \geq 2$) with dimensions $i \times j \times \ldots \times k$, then **E** (used as other than an lvalue) is converted to a pointer to an $(n-1)$-dimensional array with dimensions $j \times \ldots \times k$. If the unary ***** operator is applied to this pointer explicitly, or implicitly as a result of subscripting, the result is the pointed-to $(n-1)$-dimensional array, which itself is converted into a pointer if used as other than an lvalue. It follows from this that arrays are stored in row-major order (last subscript varies fastest).

Example

[4] Consider the array object defined by the declaration

```
int x[3][5];
```

Here **x** is a 3×5 array of **int**s; more precisely, **x** is an array of three element objects, each of which is an array of five **int**s. In the expression **x[i]**, which is equivalent to **(*(x+(i)))**, **x** is first converted to a pointer to the initial array of five **int**s. Then **i** is adjusted according to the type of **x**, which conceptually entails multiplying **i** by the size of the object to which the pointer points, namely an array of five **int** objects. The results are added and indirection is applied to yield an array of five **int**s. When used in the expression **x[i][j]**, that in turn is converted to a pointer to the first of the **int**s, so **x[i][j]** yields an **int**.

Forward references: additive operators (6.3.6), address and indirection operators (6.3.3.2), array declarators (6.5.4.2).

6.3.2.2 Function calls

Constraints

[1] The expression that denotes the called function[44] shall have type pointer to function returning **void** or returning an object type other than an array type.

[2] If the expression that denotes the called function has a type that includes a prototype, the number of arguments shall agree with the number of parameters. Each argument shall have a type such that its value may be assigned to an object with the unqualified version of the type of its corresponding parameter.

Semantics

[3] A postfix expression followed by parentheses **()** containing a possibly empty, comma-separated list of expressions is a function call. The postfix expression denotes the called function. The list of expressions specifies the arguments to the function.

[4] If the expression that precedes the parenthesized argument list in a function call consists solely of an identifier, and if no declaration is visible for this identifier, the identifier is implicitly declared exactly as if, in the innermost block containing the function call, the declaration

extern int *identifier***();**

appeared.[45]

[5] An argument may be an expression of any object type. In preparing for the call to a function, the arguments are evaluated, and each parameter is assigned the value of the corresponding argument.[46] If the expression that denotes the called function has type pointer to function returning an object type, the function call expression has the same type as that object type, and has the value determined as specified in 6.6.6.4. Otherwise, the function call has type **void**. *

---

44. Most often, this is the result of converting an identifier that is a function designator.

45. That is, an identifier with block scope declared to have external linkage with type function without parameter information and returning an **int**. If in fact it is not defined as having type ‘‘function returning **int**,’’ the behavior is undefined.

46. A function may change the values of its parameters, but these changes cannot affect the values of the arguments. On the other hand, it is possible to pass a pointer to an object, and the function may change the value of the object pointed to. A parameter declared to have array or function type is converted to a parameter with a pointer type as described in 6.7.1.

[6] If the expression that denotes the called function has a type that does not include a prototype, the integral promotions are performed on each argument and arguments that have type **`float`** are promoted to **`double`**. These are called the *default argument promotions*. If the number of arguments does not agree with the number of parameters, the behavior is undefined. If the function is defined with a type that does not include a prototype, and the types of the arguments after promotion are not compatible with those of the parameters after promotion, the behavior is undefined. If the function is defined with a type that includes a prototype, and the types of the arguments after promotion are not compatible with the types of the parameters, or if the prototype ends with an ellipsis (**`, ...`**), the behavior is undefined.

[7] If the expression that denotes the called function has a type that includes a prototype, the arguments are implicitly converted, as if by assignment, to the types of the corresponding parameters, taking the type of each parameter to be the unqualified version of its declared type. The ellipsis notation in a function prototype declarator causes argument type conversion to stop after the last declared parameter. The default argument promotions are performed on trailing arguments. If the function is defined with a type that is not compatible with the type (of the expression) pointed to by the expression that denotes the called function, the behavior is undefined.

[8] No other conversions are performed implicitly; in particular, the number and types of arguments are not compared with those of the parameters in a function definition that does not include a function prototype declarator.

[9] The order of evaluation of the function designator, the arguments, and subexpressions within the arguments is unspecified, but there is a sequence point before the actual call.

[10] Recursive function calls shall be permitted, both directly and indirectly through any chain of other functions.

Example

[11] In the function call

```
(*pf[f1()]) (f2(), f3() + f4())
```

the functions **`f1`**, **`f2`**, **`f3`**, and **`f4`** may be called in any order. All side effects shall be completed before the function pointed to by **`pf[f1()]`** is entered.

Forward references: function declarators (including prototypes) (6.5.4.3), function definitions (6.7.1), the **`return`** statement (6.6.6.4), simple assignment (6.3.16.1).

6.3.2.3 Structure and union members

Constraints

[1] The first operand of the **`.`** operator shall have a qualified or unqualified structure or union type, and the second operand shall name a member of that type.

[2] The first operand of the **`->`** operator shall have type ‘‘pointer to qualified or unqualified structure’’ or ‘‘pointer to qualified or unqualified union,’’ and the second operand shall name a member of the type pointed to.

Semantics

[3] A postfix expression followed by a dot **.** and an identifier designates a member of a structure or union object. The value is that of the named member, and is an lvalue if the first expression is an lvalue. If the first expression has qualified type, the result has the so-qualified version of the type of the designated member.

[4] A postfix expression followed by an arrow **->** and an identifier designates a member of a structure or union object. The value is that of the named member of the object to which the first expression points, and is an lvalue.[47] If the first expression is a pointer to a qualified type, the result has the so-qualified version of the type of the designated member.

[5] With one exception, if a member of a union object is accessed after a value has been stored in a different member of the object, the behavior is implementation-defined.[48] One special guarantee is made in order to simplify the use of unions: If a union contains several structures that share a common initial sequence (see below), and if the union object currently contains one of these structures, it is permitted to inspect the common initial part of any of them. Two structures share a *common initial sequence* if corresponding members have compatible types (and, for bit-fields, the same widths) for a sequence of one or more initial members.

Examples

[6]

1. If **f** is a function returning a structure or union, and **x** is a member of that structure or union, **f().x** is a valid postfix expression but is not an lvalue.

2. The following is a valid fragment:

47. If **&E** is a valid pointer expression (where **&** is the ''address-of'' operator, which generates a pointer to its operand), the expression **(&E)->MOS** is the same as **E.MOS**.

48. The ''byte orders'' for scalar types are invisible to isolated programs that do not indulge in type punning (for example, by assigning to one member of a union and inspecting the storage by accessing another member that is an appropriately sized array of character type), but must be accounted for when conforming to externally imposed storage layouts.

```
union {
     struct {
          int    alltypes;
     } n;
     struct {
          int    type;
          int    intnode;
     } ni;
     struct {
          int    type;
          double doublenode;
     } nf;
} u;
u.nf.type = 1;
u.nf.doublenode = 3.14;
/*...*/
if (u.n.alltypes == 1)
     /*...*/ sin(u.nf.doublenode) /*...*/
```

Forward references: address and indirection operators (6.3.3.2), structure and union specifiers (6.5.2.1).

6.3.2.4 Postfix increment and decrement operators

Constraints

[1] The operand of the postfix increment or decrement operator shall have qualified or unqualified real or pointer type and shall be a modifiable lvalue. |

Semantics

[2] The result of the postfix **++** operator is the value of the operand. After the result is obtained, the value of the operand is incremented. (That is, the value 1 of the appropriate type is added to it.) See the discussions of additive operators and compound assignment for information on constraints, types, and conversions and the effects of operations on pointers. The side effect of updating the stored value of the operand shall occur between the previous and the next sequence point.

[3] The postfix **--** operator is analogous to the postfix **++** operator, except that the value of the operand is decremented (that is, the value 1 of the appropriate type is subtracted from it).

Forward references: additive operators (6.3.6), compound assignment (6.3.16.2).

6.3.3 Unary operators

Syntax

[1]

```
unary-expression:
        postfix-expression
        ++ unary-expression
        -- unary-expression
        unary-operator cast-expression
        sizeof unary-expression
        sizeof ( type-name )

unary-operator: one of
        &  *  +  -  ~  !
```

6.3.3.1 Prefix increment and decrement operators

Constraints

[1] The operand of the prefix increment or decrement operator shall have qualified or unqualified real or pointer type and shall be a modifiable lvalue.

Semantics

[2] The value of the operand of the prefix `++` operator is incremented. The result is the new value of the operand after incrementation. The expression `++E` is equivalent to `(E+=1)`. See the discussions of additive operators and compound assignment for information on constraints, types, side effects, and conversions and the effects of operations on pointers.

[3] The prefix `--` operator is analogous to the prefix `++` operator, except that the value of the operand is decremented.

Forward references: additive operators (6.3.6), compound assignment (6.3.16.2).

6.3.3.2 Address and indirection operators

Constraints

[1] The operand of the unary `&` operator shall be either a function designator or an lvalue that designates an object that is not a bit-field and is not declared with the `register` storage-class specifier.

[2] The operand of the unary `*` operator shall have pointer type.

Semantics

[3] The result of the unary `&` (address-of) operator is a pointer to the object or function designated by its operand. If the operand has type ‘‘*type*,’’ the result has type ‘‘pointer to *type*.’’

[4] The unary `*` operator denotes indirection. If the operand points to a function, the result is a function designator; if it points to an object, the result is an lvalue designating the object. If the operand has type ‘‘pointer to *type*,’’ the result has type ‘‘*type*.’’ If an invalid value has been assigned to the pointer, the behavior of the unary `*` operator is undefined.[49]

Forward references: storage-class specifiers (6.5.1), structure and union specifiers (6.5.2.1).

6.3.3.3 Unary arithmetic operators

Constraints

[1] The operand of the unary `+` or `-` operator shall have arithmetic type; of the `~` operator, integral type; of the `!` operator, scalar type.

Semantics

[2] The result of the unary `+` operator is the value of its operand. The integral promotion is performed on the operand, and the result has the promoted type.

[3] The result of the unary `-` operator is the negative of its operand. The integral promotion is performed on the operand, and the result has the promoted type.

[4] The result of the `~` operator is the bitwise complement of its operand (that is, each bit in the result is set if and only if the corresponding bit in the converted operand is not set). The integral promotion is performed on the operand, and the result has the promoted type. The expression `~E` is equivalent to `(ULLONG_MAX-E)` if `E` is promoted to type `unsigned long long`, to `(ULONG_MAX-E)` if `E` is promoted to type `unsigned long`, to `(UINT_MAX-E)` if `E` is promoted to type `unsigned int`. (The constants `ULLONG_MAX`, `ULONG_MAX`, and `UINT_MAX` are defined in the header `<limits.h>`.) |

[5] The result of the logical negation operator `!` is 0 if the value of its operand compares unequal to 0, 1 if the value of its operand compares equal to 0. The result has type `int`. The expression `!E` is equivalent to `(0==E)`.

Forward references: limits `<float.h>` and `<limits.h>` (7.1.6).

---

49. It is always true that if `E` is a function designator or an lvalue that is a valid operand of the unary `&` operator, `*&E` is a function designator or an lvalue equal to `E`. If `*P` is an lvalue and `T` is the name of an object pointer type, `*(T)P` is an lvalue that has a type compatible with that to which `T` points.

    [5] Among the invalid values for dereferencing a pointer by the unary `*` operator are a null pointer, an address inappropriately aligned for the type of object pointed to, and the address of an automatic storage duration object when execution of the block with which the object is associated has terminated.

6.3.3.4 The `sizeof` operator

Constraints

[1] The **`sizeof`** operator shall not be applied to an expression that has function type or an incomplete type, to the parenthesized name of such a type, or to an lvalue that designates a bit-field object.

Semantics

[2] The **`sizeof`** operator yields the size (in bytes) of its operand, which may be an expression or the parenthesized name of a type. The size is determined from the type of the operand, which is not itself evaluated. The result is an integer constant.

[3] When applied to an operand that has type **`char`**, **`unsigned char`**, or **`signed char`**, (or a qualified version thereof) the result is 1. When applied to an operand that has array type, the result is the total number of bytes in the array.[50] When applied to an operand that has structure or union type, the result is the total number of bytes in such an object, including internal and trailing padding.

[4] The value of the result is implementation-defined, and its type (an unsigned integral type) is **`size_t`** defined in the **`<stddef.h>`** header.

Examples

[5]

1. A principal use of the **`sizeof`** operator is in communication with routines such as storage allocators and I/O systems. A storage-allocation function might accept a size (in bytes) of an object to allocate and return a pointer to **`void`**. For example:

   ```
   extern void *alloc(size_t);
   double *dp = alloc(sizeof *dp);
   ```

   The implementation of the **`alloc`** function should ensure that its return value is aligned suitably for conversion to a pointer to **`double`**.

2. Another use of the **`sizeof`** operator is to compute the number of elements in an array:

   ```
   sizeof array / sizeof array[0]
   ```

Forward references: common definitions **`<stddef.h>`** (7.1.6), declarations (6.5), structure and union specifiers (6.5.2.1), type names (6.5.5).

---

50. When applied to a parameter declared to have array or function type, the **`sizeof`** operator yields the size of the pointer obtained by converting as in 6.2.2.1; see 6.7.1.

6.3.4 Cast operators

Syntax

[1]

> *cast-expression:*
> > *unary-expression*
> > **(** *type-name* **)** *cast-expression*

Constraints

[2] Unless the type name specifies a void type, the type name shall specify qualified or unqualified scalar type and the operand shall have scalar type.

Semantics

[3] Preceding an expression by a parenthesized type name converts the value of the expression to the named type. This construction is called a *cast*.[51] A cast that specifies no conversion has no effect on the type or value of an expression.[52]

[4] Conversions that involve pointers (other than as permitted by the constraints of 6.3.16.1) shall be specified by means of an explicit cast; they have implementation-defined and undefined aspects:

> A pointer may be converted to an integral type. The size of integer required and the result are implementation-defined. If the space provided is not long enough, the behavior is undefined.
>
> An arbitrary integer may be converted to a pointer. The result is implementation-defined.[53]
>
> A pointer to an object or incomplete type may be converted to a pointer to a different object type or a different incomplete type. The resulting pointer might not be valid if it is improperly aligned for the type pointed to. It is guaranteed, however, that a pointer to an object of a given alignment may be converted to a pointer to an object of the same alignment or a less strict alignment and back again; the result shall compare equal to the original pointer. (An object that has character type has the least strict alignment.)

---

51. A cast does not yield an lvalue. Thus, a cast to a qualified type has the same effect as a cast to the unqualified version of the type.

52. If the value of the expression is represented with greater precision or range than required by the type named by the cast (6.2.1.7), then the cast specifies a conversion even if the type of the expression is the same as the named type.

53. The mapping functions for converting a pointer to an integer or an integer to a pointer are intended to be consistent with the addressing structure of the execution environment.

A pointer to a function of one type may be converted to a pointer to a function of another type and back again; the result shall compare equal to the original pointer. If a converted pointer is used to call a function that has a type that is not compatible with the type of the called function, the behavior is undefined.

Forward references: equality operators (6.3.9), function declarators (including prototypes) (6.5.4.3), simple assignment (6.3.16.1), type names (6.5.5).

6.3.5 Multiplicative operators

Syntax

[1]

multiplicative-expression:
cast-expression
multiplicative-expression **`*`** *cast-expression*
multiplicative-expression **`/`** *cast-expression*
multiplicative-expression **`%`** *cast-expression*

Constraints

[2] Each of the operands shall have arithmetic type. The operands of the **`%`** operator shall have integral type.

Semantics

[3] The usual arithmetic conversions are performed on the operands. If either operand has complex type, then the result has complex type. [**Editor: This should be moved to the usual arithmetic conversions.**]

[4] The result of the binary **`*`** operator is the product of the operands.

[5] The result of the **`/`** operator is the quotient from the division of the first operand by the second; the result of the **`%`** operator is the remainder. In both operations, if the value of the second operand is zero, the behavior is undefined.

[6] When integers are divided, the result of the **`/`** operator is the algebraic quotient with any fractional part discarded.[54] If the quotient **`a/b`** is representable, the expression **`(a/b)*b + a%b`** shall equal **`a`**.

54. This is often called *truncation toward zero*.

6.3.6 Additive operators

Syntax

[1]

additive-expression:
multiplicative-expression
additive-expression **+** *multiplicative-expression*
additive-expression **-** *multiplicative-expression*

Constraints

[2] For addition, either both operands shall have arithmetic type, or one operand shall be a pointer to an object type and the other shall have integral type. (Incrementing is equivalent to adding 1.)

[3] For subtraction, one of the following shall hold:

— both operands have arithmetic type;

— both operands are pointers to qualified or unqualified versions of compatible object types; or

— the left operand is a pointer to an object type and the right operand has integral type. (Decrementing is equivalent to subtracting 1.)

Semantics

[4] If both operands have arithmetic type, the usual arithmetic conversions are performed on them. If either operand has complex type, then the result has complex type. [**Editor: This should be moved to the usual arithmetic conversions.**]

[5] The result of the binary **+** operator is the sum of the operands.

[6] The result of the binary **-** operator is the difference resulting from the subtraction of the second operand from the first.

[7] For the purposes of these operators, a pointer to a nonarray object behaves the same as a pointer to the first element of an array of length one with the type of the object as its element type.

[8] When an expression that has integral type is added to or subtracted from a pointer, the result has the type of the pointer operand. If the pointer operand points to an element of an array object, and the array is large enough, the result points to an element offset from the original element such that the difference of the subscripts of the resulting and original array elements equals the integral expression. In other words, if the expression **P** points to the i-th element of an array object, the expressions **(P)+N** (equivalently, **N+(P)**) and **(P)-N** (where **N** has the value n) point to, respectively, the $i+n$-th and $i-n$-th elements of the array object, provided they exist. Moreover, if the expression **P** points to the last element of an array object, the expression **(P)+1** points one past the last element of the array object, and if the expression **Q** points one past the last element of an array object, the expression **(Q)-1**

points to the last element of the array object. If both the pointer operand and the result point to elements of the same array object, or one past the last element of the array object, the evaluation shall not produce an overflow; otherwise, the behavior is undefined. Unless both the pointer operand and the result point to elements of the same array object, or the pointer operand points one past the last element of an array object and the result points to an element of the same array object, the behavior is undefined if the result is used as an operand of the unary `*` operator.

[9] When two pointers to elements of the same array object are subtracted, the result is the difference of the subscripts of the two array elements. The size of the result is implementation-defined, and its type (a signed integral type) is **`ptrdiff_t`** defined in the **`<stddef.h>`** header. As with any other arithmetic overflow, if the result does not fit in the space provided, the behavior is undefined. In other words, if the expressions **`P`** and **`Q`** point to, respectively, the i-th and j-th elements of an array object, the expression **`(P)-(Q)`** has the value $i-j$ provided the value fits in an object of type **`ptrdiff_t`**. Moreover, if the expression **`P`** points either to an element of an array object or one past the last element of an array object, and the expression **`Q`** points to the last element of the same array object, the expression **`((Q)+1)-(P)`** has the same value as **`((Q)-(P))+1`** and as **`-((P)-((Q)+1))`**, and has the value zero if the expression **`P`** points one past the last element of the array object, even though the expression **`(Q)+1`** does not point to an element of the array object. Unless both pointers point to elements of the same array object, or one past the last element of the array object, the behavior is undefined.[55]

Forward references: common definitions **`<stddef.h>`** (7.1.6).

---

55. Another way to approach pointer arithmetic is first to convert the pointer(s) to character pointer(s): In this scheme the integral expression added to or subtracted from the converted pointer is first multiplied by the size of the object originally pointed to, and the resulting pointer is converted back to the original type. For pointer subtraction, the result of the difference between the character pointers is similarly divided by the size of the object originally pointed to.

    [10] When viewed in this way, an implementation need only provide one extra byte (which may overlap another object in the program) just after the end of the object in order to satisfy the ''one past the last element'' requirements.

6.3.7 Bitwise shift operators

Syntax

[1]

shift-expression:
    additive-expression
    shift-expression **<<** *additive-expression*
    shift-expression **>>** *additive-expression*

Constraints

[2] Each of the operands shall have integral type.

Semantics

[3] The integral promotions are performed on each of the operands. The type of the result is that of the promoted left operand. If the value of the right operand is negative or is greater than or equal to the width in bits of the promoted left operand, the behavior is undefined.

[4] The result of **`E1 << E2`** is **`E1`** left-shifted **`E2`** bit positions; vacated bits are filled with zeros. If **`E1`** has an unsigned type, the value of the result is **`E1`** multiplied by the quantity, 2 raised to the power **`E2`**, reduced modulo **`ULLONG_MAX+1`** if **`E1`** has type **`unsigned long long`**, **`ULONG_MAX+1`** if **`E1`** has type **`unsigned long`**, **`UINT_MAX+1`** otherwise. (The constants **`ULLONG_MAX`**, **`ULONG_MAX`**, and **`UINT_MAX`** are defined in the header **`<limits.h>`**.)

[5] The result of **`E1 >> E2`** is **`E1`** right-shifted **`E2`** bit positions. If **`E1`** has an unsigned type or if **`E1`** has a signed type and a nonnegative value, the value of the result is the integral part of the quotient of **`E1`** divided by the quantity, 2 raised to the power **`E2`**. If **`E1`** has a signed type and a negative value, the resulting value is implementation-defined.

6.3.8 Relational operators

Syntax

[1]

relational-expression:
    shift-expression
    relational-expression **<** *shift-expression*
    relational-expression **>** *shift-expression*
    relational-expression **<=** *shift-expression*
    relational-expression **>=** *shift-expression*

Constraints

[2] One of the following shall hold:

— both operands have real type;

— both operands are pointers to qualified or unqualified versions of compatible object types; or

— both operands are pointers to qualified or unqualified versions of compatible incomplete types.

Semantics

[3] If both of the operands have arithmetic type, the usual arithmetic conversions are performed.

[4] For the purposes of these operators, a pointer to a nonarray object behaves the same as a pointer to the first element of an array of length one with the type of the object as its element type.

[5] When two pointers are compared, the result depends on the relative locations in the address space of the objects pointed to. If the objects pointed to are members of the same aggregate object, pointers to structure members declared later compare higher than pointers to members declared earlier in the structure, and pointers to array elements with larger subscript values compare higher than pointers to elements of the same array with lower subscript values. All pointers to members of the same union object compare equal. If the objects pointed to are not members of the same aggregate or union object, the result is undefined, with the following exception. If the expression `P` points to an element of an array object and the expression `Q` points to the last element of the same array object, the pointer expression `Q+1` compares higher than `P`, even though `Q+1` does not point to an element of the array object.

[6] If two pointers to object or incomplete types both point to the same object, or both point one past the last element of the same array object, they compare equal. If two pointers to object or incomplete types compare equal, both point to the same object, or both point one past the last element of the same array object.[56]

[7] Each of the operators `<` (less than), `>` (greater than), `<=` (less than or equal to), and `>=` (greater than or equal to) shall yield 1 if the specified relation is true and 0 if it is false.[57] The result has type `int`.

56. If invalid prior pointer operations, such as accesses outside array bounds, produced undefined behavior, the effect of subsequent comparisons is undefined.

57. The expression `a<b<c` is not interpreted as in ordinary mathematics. As the syntax indicates, it means `(a<b)<c`; in other words, ‘‘if `a` is less than `b` compare 1 to `c`; otherwise, compare 0 to `c`.’’

6.3.9 Equality operators

Syntax

[1]

> *equality-expression:*
> *relational-expression*
> *equality-expression* **==** *relational-expression*
> *equality-expression* **!=** *relational-expression*

Constraints

[2] One of the following shall hold:

— both operands have arithmetic type;

— both operands are pointers to qualified or unqualified versions of compatible types;

— one operand is a pointer to an object or incomplete type and the other is a pointer to a qualified or unqualified version of **void**; or

— one operand is a pointer and the other is a null pointer constant.

Semantics

[3] The **==** (equal to) and the **!=** (not equal to) operators are analogous to the relational operators except for their lower precedence.[58] Where the operands have types and values suitable for the relational operators, the semantics detailed in 6.3.8 apply. Values of complex types are equal if and only if both their real parts are equal and also their imaginary parts are equal. Any two values of arithmetic types are equal if and only if the results of their conversion to the complex type corresponding to the common real type determined by the usual arithmetic conversions are equal.

[4] If two pointers to object or incomplete types are both null pointers, they compare equal. If two pointers to object or incomplete types compare equal, they both are null pointers, or both point to the same object, or both point one past the last element of the same array object. If two pointers to function types are both null pointers or both point to the same function, they compare equal. If two pointers to function types compare equal, either both are null pointers, or both point to the same function. If one of the operands is a pointer to an object or incomplete type and the other has type pointer to a qualified or unqualified version of **void**, the pointer to an object or incomplete type is converted to the type of the other operand.

58. Because of the precedences, **a<b == c<d** is 1 whenever **a<b** and **c<d** have the same truth-value.

6.3.10 Bitwise AND operator

Syntax

[1]

AND-expression:
  equality-expression
  AND-expression **&** *equality-expression*

Constraints

[2] Each of the operands shall have integral type.

Semantics

[3] The usual arithmetic conversions are performed on the operands.

[4] The result of the binary **&** operator is the bitwise AND of the operands (that is, each bit in the result is set if and only if each of the corresponding bits in the converted operands is set).

6.3.11 Bitwise exclusive OR operator

Syntax

[1]

exclusive-OR-expression:
  AND-expression
  exclusive-OR-expression **^** *AND-expression*

Constraints

[2] Each of the operands shall have integral type.

Semantics

[3] The usual arithmetic conversions are performed on the operands.

[4] The result of the **^** operator is the bitwise exclusive OR of the operands (that is, each bit in the result is set if and only if exactly one of the corresponding bits in the converted operands is set).

6.3.12 Bitwise inclusive OR operator

Syntax

[1]

inclusive-OR-expression:
  exclusive-OR-expression
  inclusive-OR-expression **|** *exclusive-OR-expression*

Constraints

[2] Each of the operands shall have integral type.

Semantics

[3] The usual arithmetic conversions are performed on the operands.

[4] The result of the **|** operator is the bitwise inclusive OR of the operands (that is, each bit in the result is set if and only if at least one of the corresponding bits in the converted operands is set).

6.3.13 Logical AND operator

Syntax

[1]

> *logical-AND-expression:*
> > *inclusive-OR-expression*
> > *logical-AND-expression* **&&** *inclusive-OR-expression*

Constraints

[2] Each of the operands shall have scalar type.

Semantics

[3] The **&&** operator shall yield 1 if both of its operands compare unequal to 0; otherwise, it yields 0. The result has type **`int`**.

[4] Unlike the bitwise binary **&** operator, the **&&** operator guarantees left-to-right evaluation; there is a sequence point after the evaluation of the first operand. If the first operand compares equal to 0, the second operand is not evaluated.

6.3.14 Logical OR operator

Syntax

[1]

> *logical-OR-expression:*
> > *logical-AND-expression*
> > *logical-OR-expression* **||** *logical-AND-expression*

Constraints

[2] Each of the operands shall have scalar type.

Semantics

[3] The **||** operator shall yield 1 if either of its operands compare unequal to 0; otherwise, it yields 0. The result has type **`int`**.

[4] Unlike the bitwise **|** operator, the **||** operator guarantees left-to-right evaluation; there is a sequence point after the evaluation of the first operand. If the first operand compares unequal to 0, the second operand is not evaluated.

6.3.15 Conditional operator

Syntax

[1]

> *conditional-expression:*
>   *logical-OR-expression*
>   *logical-OR-expression* **?** *expression* **:** *conditional-expression*

Constraints

[2] The first operand shall have scalar type.

[3] One of the following shall hold for the second and third operands:

— both operands have arithmetic type;

— both operands have compatible structure or union types;

— both operands have void type;

— both operands are pointers to qualified or unqualified versions of compatible types;

— one operand is a pointer and the other is a null pointer constant; or

— one operand is a pointer to an object or incomplete type and the other is a pointer to a qualified or unqualified version of **`void`**.

Semantics

[4] The first operand is evaluated; there is a sequence point after its evaluation. The second operand is evaluated only if the first compares unequal to 0; the third operand is evaluated only if the first compares equal to 0; the value of the second or third operand (whichever is evaluated) is the result.[59]

[5] If both the second and third operands have arithmetic type, the usual arithmetic conversions are performed to bring them to a common type and the result has that type. If both the operands have structure or union type, the result has that type. If both operands have void type, the result has void type.

[6] If both the second and third operands are pointers or one is a null pointer constant and the other is a pointer, the result type is a pointer to a type qualified with all the type qualifiers of the types pointed-to by both operands. Furthermore, if both operands are pointers to compatible types or differently qualified versions of a compatible type, the result has the composite type; if one operand is a null pointer constant, the result has the type of the other operand; otherwise, one operand is a pointer to **`void`** or a qualified version of **`void`**, in which case the other operand is converted to type

59. A conditional expression does not yield an lvalue.

pointer to **void**, and the result has that type.

Example

[7] The common type that results when the second and third operands are pointers is determined in two independent stages. The appropriate qualifiers, for example, do not depend on whether the two pointers have compatible types.

[8] Given the declarations

```
const void *c_vp;
void *vp;
const int *c_ip;
volatile int *v_ip;
int *ip;
const char *c_cp;
```

the third column in the following table is the common type that is the result of a conditional expression in which the first two columns are the second and third operands (in either order):

```
c_vp c_ip const void *
v_ip 0    volatile int *
c_ip v_ip const volatile int *
vp   c_cp const void *
ip   c_ip const int *
vp   ip   void *
```

6.3.16 Assignment operators

Syntax

[1]

assignment-expression:
  conditional-expression
  unary-expression assignment-operator assignment-expression

assignment-operator: one of
  = *= /= %= += -= <<= >>= &= ^= |=

Constraints

[2] An assignment operator shall have a modifiable lvalue as its left operand.

Semantics

[3] An assignment operator stores a value in the object designated by the left operand. An assignment expression has the value of the left operand after the assignment, but is not an lvalue. The type of an assignment expression is the type of the left operand unless the left operand has qualified type, in which case it is the unqualified version of the type of the left operand. The side effect of updating the stored value of the left operand shall occur between the previous and the next sequence point.

[4] The order of evaluation of the operands is unspecified.

6.3.16.1 Simple assignment

Constraints

[1] One of the following shall hold:[60]

— the left operand has qualified or unqualified arithmetic type and the right has arithmetic type;

— the left operand has a qualified or unqualified version of a structure or union type compatible with the type of the right;

— both operands are pointers to qualified or unqualified versions of compatible types, and the type pointed to by the left has all the qualifiers of the type pointed to by the right;

— one operand is a pointer to an object or incomplete type and the other is a pointer to a qualified or unqualified version of **`void`**, and the type pointed to by the left has all the qualifiers of the type pointed to by the right; or

— the left operand is a pointer and the right is a null pointer constant.

Semantics

[2] In *simple assignment* (**`=`**), the value of the right operand is converted to the type of the assignment expression and replaces the value stored in the object designated by the left operand.

[3] If the value being stored in an object is accessed from another object that overlaps in any way the storage of the first object, then the overlap shall be exact and the two objects shall have qualified or unqualified versions of a compatible type; otherwise, the behavior is undefined.

Example

[4]

1. In the program fragment

```
int f(void);
char c;
/*...*/
/*...*/ ((c = f()) == -1) /*...*/
```

the **`int`** value returned by the function may be truncated when stored in the

---

60. The asymmetric appearance of these constraints with respect to type qualifiers is due to the conversion (specified in 6.2.2.1) that changes lvalues to ''the value of the expression'' which removes any type qualifiers from the type category of the expression.

char, and then converted back to **int** width prior to the comparison. In an implementation in which ''plain'' **char** has the same range of values as **unsigned char** (and **char** is narrower than **int**), the result of the conversion cannot be negative, so the operands of the comparison can never compare equal. Therefore, for full portability, the variable **c** should be declared as **int**.

2. In the fragment: *

```
char c;
int i;
long l;

l = ( c = i );
```

the value of **i** is converted to the type of the assignment-expression **c = i**, that is, **char** type. The value of the expression enclosed in parentheses is then converted to the type of the outer assignment-expression, that is, **long** type. |

6.3.16.2 Compound assignment

Constraints

[1] For the operators **+=** and **-=** only, either the left operand shall be a pointer to an object type and the right shall have integral type, or the left operand shall have qualified or unqualified arithmetic type and the right shall have arithmetic type.

[2] For the other operators, each operand shall have arithmetic type consistent with those allowed by the corresponding binary operator.

Semantics

[3] A *compound assignment* of the form **E1** *op*= **E2** differs from the simple assignment expression **E1 = E1** *op* **(E2)** only in that the lvalue **E1** is evaluated only once.

6.3.17 Comma operator

Syntax

[1] |

expression:
  assignment-expression
  expression **,** *assignment-expression*

Semantics

[2] The left operand of a comma operator is evaluated as a void expression; there is a sequence point after its evaluation. Then the right operand is evaluated; the result has its type and value.[61]

Example

[3] As indicated by the syntax, in contexts where a comma is a punctuator (in lists of arguments to functions and lists of initializers) the comma operator as described in this subclause cannot appear. On the other hand, it can be used within a parenthesized expression or within the second expression of a conditional operator in such contexts. In the function call

```
f(a, (t=3, t+2), c)
```

the function has three arguments, the second of which has the value 5.

Forward references: initialization (6.5.7).

61. A comma operator does not yield an lvalue.

6.4 Constant expressions

Syntax

[1]

constant-expression:
  conditional-expression

Description

[2] A *constant expression* can be evaluated during translation rather than runtime, and accordingly may be used in any place that a constant may be.

Constraints

[3] Constant expressions shall not contain assignment, increment, decrement, function-call, or comma operators, except when they are contained within the operand of a **`sizeof`** operator.[62]

[4] Each constant expression shall evaluate to a constant that is in the range of representable values for its type.

Semantics

[5] An expression that evaluates to a constant is required in several contexts.[63] If a floating expression is evaluated in the translation environment, the arithmetic precision and range shall be at least as great as if the expression were being evaluated in the execution environment.

[6] An *integral constant expression* shall have integral type and shall only have operands that are integer constants, enumeration constants, character constants, **`sizeof`** expressions, and floating constants that are the immediate operands of casts. Cast operators in an integral constant expression shall only convert arithmetic types to integral types, except as part of an operand to the **`sizeof`** operator.

[7] More latitude is permitted for constant expressions in initializers. Such a constant expression shall evaluate to one of the following:

— an arithmetic constant expression,

— a null pointer constant,

---

62. The operand of a **`sizeof`** operator is not evaluated (6.3.3.4), and thus any operator in 6.3 may be used.

63. An integral constant expression must be used to specify the size of a bit-field member of a structure, the value of an enumeration constant, the size of an array, or the value of a **`case`** constant. Further constraints that apply to the integral constant expressions used in conditional-inclusion preprocessing directives are discussed in 6.8.1.

— an address constant, or

— an address constant for an object type plus or minus an integral constant expression.

[8] An *arithmetic constant expression* shall have arithmetic type and shall only have operands that are integer constants, floating constants, enumeration constants, character constants, and **`sizeof`** expressions. Cast operators in an arithmetic constant expression shall only convert arithmetic types to arithmetic types, except as part of an operand to the **`sizeof`** operator.

[9] An *address constant* is a pointer to an lvalue designating an object of static storage duration, or to a function designator; it shall be created explicitly, using the unary **`&`** operator, or implicitly, by the use of an expression of array or function type. The array-subscript **`[]`** and member-access **`.`** and **`->`** operators, the address **`&`** and indirection **`*`** unary operators, and pointer casts may be used in the creation of an address constant, but the value of an object shall not be accessed by use of these operators.

[10] An implementation may accept other forms of constant expressions.

[11] The semantic rules for the evaluation of a constant expression are the same as for nonconstant expressions.[64]

Forward references: initialization (6.5.7).

64. Thus, in the following initialization,

```
static int i = 2 || 1 / 0;
```

the expression is a valid integral constant expression with value one.

6.5 Declarations

Syntax

[1]

declaration:
  declaration-specifiers init-declarator-list$_{opt}$ **;**

declaration-specifiers:
  storage-class-specifier declaration-specifiers$_{opt}$
  type-specifier declaration-specifiers$_{opt}$
  type-qualifier declaration-specifiers$_{opt}$

init-declarator-list:
  init-declarator
  init-declarator-list **,** *init-declarator*

init-declarator:
  declarator
  declarator **=** *initializer*

Constraints

[2] A declaration shall declare at least a declarator, a tag, or the members of an enumeration.

[3] If an identifier has no linkage, there shall be no more than one declaration of the identifier (in a declarator or type specifier) with the same scope and in the same name space, except for tags as specified in 6.5.2.3.

[4] All declarations in the same scope that refer to the same object or function shall specify compatible types.

Semantics

[5] A *declaration* specifies the interpretation and attributes of a set of identifiers. A declaration that also causes storage to be reserved for an object or function named by an identifier is a *definition*.[65]

[6] The declaration specifiers consist of a sequence of specifiers that indicate the linkage, storage duration, and part of the type of the entities that the declarators denote. The init-declarator-list is a comma-separated sequence of declarators, each of which may have additional type information, or an initializer, or both. The declarators contain the identifiers (if any) being declared.

---

65. Function definitions have a different syntax, described in 6.7.1.

[7] If an identifier for an object is declared with no linkage, the type for the object shall be complete by the end of its declarator, or by the end of its init-declarator if it has an initializer.

Forward references: declarators (6.5.4), enumeration specifiers (6.5.2.2), initialization (6.5.7), tags (6.5.2.3).

6.5.1 Storage-class specifiers

Syntax

[1] |

storage-class-specifier:
  `typedef`
  `extern`
  `static`
  `auto`
  `register`

Constraints

[2] At most, one storage-class specifier may be given in the declaration specifiers in a declaration.[66]

Semantics

[3] The **`typedef`** specifier is called a ‘‘storage-class specifier’’ for syntactic convenience only; it is discussed in 6.5.6. The meanings of the various linkages and storage durations were discussed in 6.1.2.2 and 6.1.2.4.

[4] A declaration of an identifier for an object with storage-class specifier **`register`** suggests that access to the object be as fast as possible. The extent to which such suggestions are effective is implementation-defined.[67]

[5] The declaration of an identifier for a function that has block scope shall have no explicit storage-class specifier other than **`extern`**.

[6] If an aggregate or union object is declared with a storage-class specifier other than **`typedef`**, the properties resulting from the storage-class specifier, except with respect to linkage, also apply to the members of the object, and so on recursively for any aggregate or union member objects. *

66. See ‘‘future language directions’’ (6.9.3).

67. The implementation may treat any **`register`** declaration simply as an **`auto`** declaration. However, whether or not addressable storage is actually used, the address of any part of an object declared with storage-class specifier **`register`** may not be computed, either explicitly (by use of the unary **`&`** operator as discussed in 6.3.3.2) or implicitly (by converting an array name to a pointer as discussed in 6.2.2.1). Thus the only operator that can be applied to an array declared with storage-class specifier **`register`** is **`sizeof`**.

Forward references: type definitions (6.5.6).

6.5.2 Type specifiers

Syntax

[1]

type-specifier:
  `void`
  `char`
  `short`
  `int`
  `long`
  `float`
  `double`
  `complex`
  `signed`
  `unsigned`
  struct-or-union-specifier
  enum-specifier
  typedef-name

Constraints

[2] Each list of type specifiers shall be one of the following sets (delimited by commas, when there is more than one set on a line); the type specifiers may occur in any order, possibly intermixed with the other declaration specifiers.

— **`void`**

— **`char`**

— **`signed char`**

— **`unsigned char`**

— **`short`**, **`signed short`**, **`short int`**, or **`signed short int`**

— **`unsigned short`**, or **`unsigned short int`**

— **`int`**, **`signed`**, **`signed int`**, or no type specifiers

— **`unsigned`**, or **`unsigned int`**

— **`long`**, **`signed long`**, **`long int`**, or **`signed long int`**

— **`unsigned long`**, or **`unsigned long int`**

— **`long long`**, **`signed long long`**, **`long long int`**, or **`signed long long int`**

— **`unsigned long long`**, or **`unsigned long long int`**

— **`float`**

— **`double`**

— **`long double`**

— **`float complex`**

— **`double complex`**

— **`long double complex`**

— struct-or-union specifier

— enum-specifier

— typedef-name

Semantics

[3] Specifiers for structures, unions, and enumerations are discussed in 6.5.2.1 through 6.5.2.3. Declarations of typedef names are discussed in 6.5.6. The characteristics of the other types are discussed in 6.1.2.5.

[4] Each of the above comma-separated sets designates the same type, except that for bit-fields, the type **`signed int`** (or **`signed`**) may differ from **`int`** (or no type specifiers).

Forward references: enumeration specifiers (6.5.2.2), structure and union specifiers (6.5.2.1), tags (6.5.2.3), type definitions (6.5.6).

6.5.2.1 Structure and union specifiers

Syntax

[1]

struct-or-union-specifier:
struct-or-union identifier$_{opt}$ **`{`** *struct-declaration-list* **`}`**
struct-or-union identifier

struct-or-union:
`struct`
`union`

struct-declaration-list:
struct-declaration
struct-declaration-list struct-declaration

struct-declaration:
specifier-qualifier-list struct-declarator-list **`;`**

specifier-qualifier-list:
    type-specifier specifier-qualifier-list$_{opt}$
    type-qualifier specifier-qualifier-list$_{opt}$

struct-declarator-list:
    struct-declarator
    struct-declarator-list **,** *struct-declarator*

struct-declarator:
    declarator
    declarator$_{opt}$ **:** *constant-expression*

Constraints

[2] A structure or union shall not contain a member with incomplete or function type. Hence it shall not contain an instance of itself (but may contain a pointer to an instance of itself).

[3] The expression that specifies the width of a bit-field shall be an integral constant expression that has nonnegative value that shall not exceed the number of bits in an ordinary object of compatible type. If the value is zero, the declaration shall have no declarator.

Semantics

[4] As discussed in 6.1.2.5, a structure is a type consisting of a sequence of named members, whose storage is allocated in an ordered sequence, and a union is a type consisting of a sequence of named members, whose storage overlap.

[5] Structure and union specifiers have the same form.

[6] The presence of a struct-declaration-list in a struct-or-union-specifier declares a new type, within a translation unit. The struct-declaration-list is a sequence of declarations for the members of the structure or union. If the struct-declaration-list contains no named members, the behavior is undefined. The type is incomplete until after the **}** that terminates the list.

[7] A member of a structure or union may have any object type. In addition, a member may be declared to consist of a specified number of bits (including a sign bit, if any). Such a member is called a *bit-field*;[68] its width is preceded by a colon.

[8] A bit-field shall have a type that is a qualified or unqualified version of one of **int**, **unsigned int**, or **signed int**. Whether the high-order bit position of a (possibly qualified) ‘‘plain’’ **int** bit-field is treated as a sign bit is implementation-defined. A bit-field is interpreted as an integral type consisting of the specified

68. The unary **&** (address-of) operator may not be applied to a bit-field object; thus, there are no pointers to or arrays of bit-field objects.

number of bits.

[9] An implementation may allocate any addressable storage unit large enough to hold a bit-field. If enough space remains, a bit-field that immediately follows another bit-field in a structure shall be packed into adjacent bits of the same unit. If insufficient space remains, whether a bit-field that does not fit is put into the next unit or overlaps adjacent units is implementation-defined. The order of allocation of bit-fields within a unit (high-order to low-order or low-order to high-order) is implementation-defined. The alignment of the addressable storage unit is unspecified.

[10] A bit-field declaration with no declarator, but only a colon and a width, indicates an unnamed bit-field.[69] As a special case of this, a bit-field structure member with a width of 0 indicates that no further bit-field is to be packed into the unit in which the previous bit-field, if any, was placed.

[11] Each non-bit-field member of a structure or union object is aligned in an implementation-defined manner appropriate to its type.

[12] Within a structure object, the non-bit-field members and the units in which bit-fields reside have addresses that increase in the order in which they are declared. A pointer to a structure object, suitably converted, points to its initial member (or if that member is a bit-field, then to the unit in which it resides), and vice versa. There may therefore be unnamed padding within a structure object, but not at its beginning, as necessary to achieve the appropriate alignment.

[13] The size of a union is sufficient to contain the largest of its members. The value of at most one of the members can be stored in a union object at any time. A pointer to a union object, suitably converted, points to each of its members (or if a member is a bit-field, then to the unit in which it resides), and vice versa.

[14] There may also be unnamed padding at the end of a structure or union, as necessary to achieve the appropriate alignment were the structure or union to be an element of an array.

Forward references: tags (6.5.2.3).

6.5.2.2 Enumeration specifiers

Syntax

[1]

enum-specifier:
  `enum` *identifier*$_{opt}$ **`{`** *enumerator-list* **`}`**
  `enum` *identifier*

69. An unnamed bit-field structure member is useful for padding to conform to externally imposed layouts.

enumerator-list:
  enumerator
  enumerator-list **,** *enumerator*

enumerator:
  enumeration-constant
  enumeration-constant **=** *constant-expression*

Constraints

[2] The expression that defines the value of an enumeration constant shall be an integral constant expression that has a value representable as an **int**.

Semantics

[3] The identifiers in an enumerator list are declared as constants that have type **int** and may appear wherever such are permitted.[70] An enumerator with **=** defines its enumeration constant as the value of the constant expression. If the first enumerator has no **=**, the value of its enumeration constant is 0. Each subsequent enumerator with no **=** defines its enumeration constant as the value of the constant expression obtained by adding 1 to the value of the previous enumeration constant. (The use of enumerators with **=** may produce enumeration constants with values that duplicate other values in the same enumeration.) The enumerators of an enumeration are also known as its members.

[4] Each enumerated type shall be compatible with an integer type. The choice of type is implementation-defined, but shall be capable of representing the values of all the members of the enumeration.

[5] The enumerated type is complete at the **}** that terminates the list of enumerator declarations. |

Example

[6] |

70. Thus, the identifiers of enumeration constants declared in the same scope shall all be distinct from each other and from other identifiers declared in ordinary declarators.

```
enum hue { chartreuse, burgundy, claret=20, winedark };
/*...*/
enum hue col, *cp;
/*...*/
col = claret;
cp = &col;
/*...*/
/*...*/ (*cp != burgundy) /*...*/
```

makes **hue** the tag of an enumeration, and then declares **col** as an object that has that type and **cp** as a pointer to an object that has that type. The enumerated values are in the set { 0, 1, 20, 21 }.

Forward references: tags (6.5.2.3).

6.5.2.3 Tags

Semantics

[1] A type specifier of the form

struct-or-union identifier **{** *struct-declaration-list* **}**

or

enum *identifier* **{** *enumerator-list* **}**

declares the identifier to be the *tag* of the structure, union, or enumeration specified by the list. The list defines the *structure content*, *union content*, or *enumeration content*. If this declaration of the tag is visible, a subsequent declaration that uses the tag and that omits the bracketed list specifies the declared structure, union, or enumerated type. Subsequent declarations in the same scope shall omit the bracketed list.

[2] If a type specifier of the form

struct-or-union identifier

occurs prior to the **}** following the *struct-declaration-list* that defines the content, the structure or union is an incomplete type.[71] It declares a tag that specifies a type that may be used only when the size of an object of the specified type is not needed.[72] If the type is to be completed, another declaration of the tag in the same scope (but not in an enclosed block, which declares a new type known only within that block) shall define the content. A declaration of the form *

71. A similar construction with **enum** does not exist and is not necessary as there can be no mutual dependencies between the declaration of an enumerated type and any other type.

72. It is not needed, for example, when a typedef name is declared to be a specifier for a structure or union, or when a pointer to or a function returning a structure or union is being declared. (See incomplete types in 6.1.2.5.) The specification shall be complete before such a function is called or defined.

struct-or-union identifier **;**

specifies a structure or union type and declares a tag, both visible only within the scope in which the declaration occurs. It specifies a new type distinct from any type with the same tag in an enclosing scope (if any).

[3] A type specifier of the form

struct-or-union **{** *struct-declaration-list* **}**

or

enum { *enumerator-list* **}**

specifies a new structure, union, or enumerated type, within the translation unit, that can only be referred to by the declaration of which it is a part.[73]

Examples

[4]

1. This mechanism allows declaration of a self-referential structure.

```
struct tnode {
     int count;
     struct tnode *left, *right;
};
```

specifies a structure that contains an integer and two pointers to objects of the same type. Once this declaration has been given, the declaration

```
struct tnode s, *sp;
```

declares **s** to be an object of the given type and **sp** to be a pointer to an object of the given type. With these declarations, the expression **sp->left** refers to the left **struct tnode** pointer of the object to which **sp** points; the expression **s.right->count** designates the **count** member of the right **struct tnode** pointed to from **s**.

[5] The following alternative formulation uses the **typedef** mechanism:

```
typedef struct tnode TNODE;
struct tnode {
     int count;
     TNODE *left, *right;
};
TNODE s, *sp;
```

73. Of course, when the declaration is of a typedef name, subsequent declarations can make use of the typedef name to declare objects having the specified structure, union, or enumerated type.

2. To illustrate the use of prior declaration of a tag to specify a pair of mutually referential structures, the declarations

```
struct s1 { struct s2 *s2p; /*...*/ }; /* D1 */
struct s2 { struct s1 *s1p; /*...*/ }; /* D2 */
```

specify a pair of structures that contain pointers to each other. Note, however, that if **s2** were already declared as a tag in an enclosing scope, the declaration **D1** would refer to *it*, not to the tag **s2** declared in **D2**. To eliminate this context sensitivity, the declaration

```
struct s2;
```

may be inserted ahead of **D1**. This declares a new tag **s2** in the inner scope; the declaration **D2** then completes the specification of the new type.

3.

[6] An enumeration type is compatible with some integral type. An implementation may delay the choice of which integral type until all enumeration constants have been seen. Thus in: *

```
enum f { c = sizeof(enum f) };
```

the behavior is undefined since the size of the respective enumeration type is not necessarily known when **sizeof** is encountered.

Forward references: type definitions (6.5.6).

6.5.3 Type qualifiers

Syntax

[1]

type-qualifier:
    const
    restrict
    volatile

Constraints

[2] If the same qualifier appears more than once in the same specifiers list of qualifier list, either directly or via one or more **typedef**s, the behavior shall be the same as if it appeared only once.

[3] Types other than pointer types derived from object or incomplete types shall not be restrict-qualified.

Semantics

[4] The properties associated with qualified types are meaningful only for expressions that are lvalues.[74]

[5] If an attempt is made to modify an object defined with a const-qualified type through use of an lvalue with non-const-qualified type, the behavior is undefined. If an attempt is made to refer to an object defined with a volatile-qualified type through use of an lvalue with non-volatile-qualified type, the behavior is undefined.[75]

[6] An object that has volatile-qualified type may be modified in ways unknown to the implementation or have other unknown side effects. Therefore any expression referring to such an object shall be evaluated strictly according to the rules of the abstract machine, as described in 5.1.2.3. Furthermore, at every sequence point the value last stored in the object shall agree with that prescribed by the abstract machine, except as modified by the unknown factors mentioned previously.[76] What constitutes an access to an object that has volatile-qualified type is implementation-defined.

[7] Let **`D`** be a declaration of an ordinary identifier that provides a means of designating an object **`P`** as a restrict-qualified pointer. *

[8] If **`D`** appears inside a block and does not have storage class **`extern`**, let **`B`** denote the block. If **`D`** appears in the list of parameter declarations of a function definition, let **`B`** denote the associated block. Otherwise, let **`B`** denote the block of **`main`** (or the block of whatever function is called at program startup in a freestanding environment). |

[9] In what follows, a pointer expression **`E`** is said to be *based* on object **`P`** if (at some sequence point in the execution of **`B`** prior to the evaluation of **`E`**) modifying **`P`** to point to a copy of the array object into which it formerly pointed would change the value of **`E`**. (In other words, **`E`** depends on the value of **`P`** itself rather than on the value of an object referenced indirectly through **`P`**. For example, if identifier **`p`** has type **`(int **restrict)`**, then the pointer expressions **`p`** and **`p+1`** are based on the restricted pointer object designated by **`p`**, but the pointer expressions **`*p`** and **`p[1]`** are not. Note that ''based'' is defined only for expressions with pointer types.) |

[10] During each execution of **`B`**, let **`O`** be the array object that is determined dynamically by all references through pointer expressions based on **`P`**. Then *all* references of values of **`O`** shall be through pointer expressions based on **`P`**. Furthermore, if **`P`** is assigned the value of a pointer expression **`E`** that is based on another restricted pointer object **`P2`**, associated with block **`B2`**, then either the execution of **`B2`** shall begin before the execution of **`B`**, or the execution of **`B2`** shall end prior to the assignment. If these requirements are not met, then the behavior is |

74. The implementation may place a **`const`** object that is not **`volatile`** in a read-only region of storage. Moreover, the implementation need not allocate storage for such an object if its address is never used.

75. This applies to those objects that behave as if they were defined with qualified types, even if they are never actually defined as objects in the program (such as an object at a memory-mapped input/output address).

76. A **`volatile`** declaration may be used to describe an object corresponding to a memory-mapped input/output port or an object accessed by an asynchronously interrupting function. Actions on objects so declared shall not be ''optimized out'' by an implementation or reordered except as permitted by the rules for evaluating expressions.

undefined.

[11] Here an execution of **B** means that portion of the execution of the program during which storage is guaranteed to be reserved for an instance of an object that is associated with **B** and has automatic storage duration. A reference to a value means either an access to or a modification of the value. During an execution of **B**, attention is confined to those references that are actually evaluated (this excludes references that appear in unevaluated expressions, and also excludes references that are ‘‘available’’, in the sense of employing visible identifiers, but do not actually appear in the text of **B**).

[12] A translator is free to ignore any or all aliasing implications of uses of **`restrict`**.

[13] If the specification of an array type includes any type qualifiers, the element type is so-qualified, not the array type. If the specification of a function type includes any type qualifiers, the behavior is undefined.[77]

[14] For two qualified types to be compatible, both shall have the identically qualified version of a compatible type; the order of type qualifiers within a list of specifiers or qualifiers does not affect the specified type.

Examples

[15]

1. An object declared

   ```
   extern const volatile int real_time_clock;
   ```

   may be modifiable by hardware, but cannot be assigned to, incremented, or decremented.

2. The following declarations and expressions illustrate the behavior when type qualifiers modify an aggregate type:

77. Both of these can only occur through the use of **`typedef`**s.

```
const struct s { int mem; } cs = { 1 };
struct s ncs;  /* the object ncs is modifiable */
typedef int A[2][3];
const A a = {{4, 5, 6}, {7, 8, 9}}; /* array of array of const int */
int *pi;
const int *pci;

ncs = cs;       /* valid */
cs = ncs;       /* violates modifiable lvalue constraint for = */
pi = &ncs.mem;  /* valid */
pi = &cs.mem;   /* violates type constraints for = */
pci = &cs.mem;  /* valid */
pi = a[0];      /* invalid: a[0] has type ``const int *'' */
```

3. The following examples show restricted pointers used as function parameters:

```
float x[100];
float *c;

void f(int n, float *restrict a, float *const b)        |
{
    int i;
    for (i = 0; i < n; i++ )                            |
        a[i] = b[i] + c[i];
}
void g(void)
{
    float d[100], e[100];
    c = x;
    f(100,   d,     e); /* defined behavior */
    f( 50,   d,  d+50); /* defined behavior */
    f( 99, d+1,     d); /* undefined behavior */
    c = d;
    f( 99, d+1,     e); /* undefined behavior */
    f( 99,   e,   d+1); /* defined behavior */
}
```

4. The following are examples of restricted pointer assignment that are undefined behavior:

```
int *restrict p1, *restrict p2;
void f (int *restrict q1, int *restrict q2)
{
    p1 = p2;   /* undefined behavior */
    p1 = q1;   /* undefined behavior */
    p1 = q2;   /* undefined behavior */
    {
        int *restrict r1, *restrict r2;
        /*...*/
        r1 = r2;   /* undefined behavior */
        q1 = r1;   /* undefined behavior */
        p1 = r1;   /* undefined behavior */
    }
}
```

6.5.4 Declarators

Syntax

[1]

declarator:
  pointer$_{opt}$ *direct-declarator*

direct-declarator:
  identifier
  (*declarator* **)**
  direct-declarator **[** *constant-expression*$_{opt}$ **]**
  direct-declarator **(** *parameter-type-list* **)**
  direct-declarator **(** *identifier-list*$_{opt}$ **)**

pointer:
  ***** *type-qualifier-list*$_{opt}$
  ***** *type-qualifier-list*$_{opt}$ *pointer*

type-qualifier-list:
  type-qualifier
  type-qualifier-list type-qualifier

parameter-type-list:
  parameter-list
  parameter-list **, ...**

parameter-list:
  parameter-declaration
  parameter-list **,** *parameter-declaration*

parameter-declaration:
declaration-specifiers declarator
declaration-specifiers abstract-declarator$_{opt}$

identifier-list:
identifier
identifier-list **,** *identifier*

Semantics

[2] Each declarator declares one identifier, and asserts that when an operand of the same form as the declarator appears in an expression, it designates a function or object with the scope, storage duration, and type indicated by the declaration specifiers.

[3] In the following subclauses, consider a declaration

```
T D1
```

where `T` contains the declaration specifiers that specify a type *T* (such as `int`) and `D1` is a declarator that contains an identifier *ident*. The type specified for the identifier *ident* in the various forms of declarator is described inductively using this notation.

[4] If, in the declaration ''`T D1`,'' `D1` has the form

identifier

then the type specified for *ident* is *T*.

[5] If, in the declaration ''`T D1`,'' `D1` has the form

```
( D )
```

then *ident* has the type specified by the declaration ''`T D`.'' Thus, a declarator in parentheses is identical to the unparenthesized declarator, but the binding of complex declarators may be altered by parentheses.

Implementation limits

[6] The implementation shall allow the specification of types that have at least 12 pointer, array, and function declarators (in any valid combinations) modifying an arithmetic, a structure, a union, or an incomplete type, either directly or via one or more `typedef`s.

Forward references: type definitions (6.5.6).

6.5.4.1 Pointer declarators

Semantics

[1] If, in the declaration ''`T D1`,'' `D1` has the form

`*` *type-qualifier-list*$_{opt}$ `D`

and the type specified for *ident* in the declaration ''`T D`'' is ''*derived-declarator-type-list T*,'' then the type specified for *ident* is ''*derived-declarator-type-list type-*

qualifier-list pointer to *T*.'' For each type qualifier in the list, *ident* is a so-qualified pointer.

[2] For two pointer types to be compatible, both shall be identically qualified and both shall be pointers to compatible types.

Example

[3] The following pair of declarations demonstrates the difference between a ''variable pointer to a constant value'' and a ''constant pointer to a variable value.''

```
const int *ptr_to_constant;
int *const constant_ptr;
```

The contents of an object pointed to by **`ptr_to_constant`** shall not be modified through that pointer, but **`ptr_to_constant`** itself may be changed to point to another object. Similarly, the contents of the **`int`** pointed to by **`constant_ptr`** may be modified, but **`constant_ptr`** itself shall always point to the same location.

[4] The declaration of the constant pointer **`constant_ptr`** may be clarified by including a definition for the type ''pointer to **`int`**.''

```
typedef int *int_ptr;
const int_ptr constant_ptr;
```

declares **`constant_ptr`** as an object that has type ''const-qualified pointer to **`int`**.''

6.5.4.2 Array declarators

Constraints

[1] The expression delimited by **`[`** and **`]`** (which specifies the size of an array) shall be an integral constant expression that has a value greater than zero.

Semantics

[2] If, in the declaration ''**`T D1`**,'' **`D1`** has the form

`D[`*constant-expression*$_{opt}$**`]`**

and the type specified for *ident* in the declaration ''**`T D`**'' is ''*derived-declarator-type-list T*,'' then the type specified for *ident* is ''*derived-declarator-type-list* array of *T*.''[78] If the size is not present, the array type is an incomplete type.

[3] For two array types to be compatible, both shall have compatible element types, and if both size specifiers are present, they shall have the same value.

Examples

78. When several ''array of'' specifications are adjacent, a multidimensional array is declared.

[4]

1.
```
float fa[11], *afp[17];
```
declares an array of **`float`** numbers and an array of pointers to **`float`** numbers.

2. Note the distinction between the declarations
```
extern int *x;
extern int y[];
```
The first declares **`x`** to be a pointer to **`int`**; the second declares **`y`** to be an array of **`int`** of unspecified size (an incomplete type), the storage for which is defined elsewhere.

Forward references: function definitions (6.7.1), initialization (6.5.7).

6.5.4.3 Function declarators (including prototypes)

Constraints

[1] A function declarator shall not specify a return type that is a function type or an array type.

[2] The only storage-class specifier that shall occur in a parameter declaration is **`register`**.

[3] An identifier list in a function declarator that is not part of a function definition shall be empty.

Semantics

[4] If, in the declaration ‘‘**`T D1`**,’’ **`D1`** has the form

`D(`*parameter-type-list***`)`**

or

`D(`*identifier-list*$_{opt}$**`)`**

and the type specified for *ident* in the declaration ‘‘**`T D`**’’ is ‘‘*derived-declarator-type-list T*,’’ then the type specified for *ident* is ‘‘*derived-declarator-type-list* function returning *T*.’’

[5] A parameter type list specifies the types of, and may declare identifiers for, the parameters of the function. If the list terminates with an ellipsis (**`, ...`**), no information about the number or types of the parameters after the comma is supplied.[79] The special case of **`void`** as the only item in the list specifies that the

79. The macros defined in the **`<stdarg.h>`** header (7.10) may be used to access arguments that correspond to the ellipsis.

function has no parameters.

[6] If, in a parameter declaration, an identifier can be treated as a typedef name or as a parameter name, it shall be taken as a typedef name. *

[7] The storage-class specifier in the declaration specifiers for a parameter declaration, if present, is ignored unless the declared parameter is one of the members of the parameter type list for a function definition.

[8] An identifier list declares only the identifiers of the parameters of the function. An empty list in a function declarator that is part of a function definition specifies that the function has no parameters. The empty list in a function declarator that is not part of a function definition specifies that no information about the number or types of the parameters is supplied.[80]

[9] For two function types to be compatible, both shall specify compatible return types.[81] Moreover, the parameter type lists, if both are present, shall agree in the number of parameters and in use of the ellipsis terminator; corresponding parameters shall have compatible types. If one type has a parameter type list and the other type is specified by a function declarator that is not part of a function definition and that contains an empty identifier list, the parameter list shall not have an ellipsis terminator and the type of each parameter shall be compatible with the type that results from the application of the default argument promotions. If one type has a parameter type list and the other type is specified by a function definition that contains a (possibly empty) identifier list, both shall agree in the number of parameters, and the type of each prototype parameter shall be compatible with the type that results from the application of the default argument promotions to the type of the corresponding identifier. (In the determination of type compatibility and of a composite type, each parameter declared with function or array type is taken as having the type that results from conversion to a pointer type, as in 6.7.1, and each parameter declared with qualified type is taken as having the unqualified version of its declared type.) *

Examples

[10] |

1. The declaration

```
int f(void), *fip(), (*pfi)();
```

   declares a function **`f`** with no parameters returning an **`int`**, a function **`fip`** with no parameter specification returning a pointer to an **`int`**, and a pointer **`pfi`** to a function with no parameter specification returning an **`int`**. It is especially useful to compare the last two. The binding of **`*fip()`** is **`*(fip())`**, so that

80. See ‘‘future language directions’’ (6.9.4).

81. If both function types are ‘‘old style,’’ parameter types are not compared.

the declaration suggests, and the same construction in an expression requires, the calling of a function **fip**, and then using indirection through the pointer result to yield an **int**. In the declarator **(*pfi)()**, the extra parentheses are necessary to indicate that indirection through a pointer to a function yields a function designator, which is then used to call the function; it returns an **int**.

[11] If the declaration occurs outside of any function, the identifiers have file scope and external linkage. If the declaration occurs inside a function, the identifiers of the functions **f** and **fip** have block scope and either internal or external linkage (depending on what file scope declarations for these identifiers are visible), and the identifier of the pointer **pfi** has block scope and no linkage.

2. The declaration

```
int (*apfi[3])(int *x, int *y);
```

declares an array **apfi** of three pointers to functions returning **int**. Each of these functions has two parameters that are pointers to **int**. The identifiers **x** and **y** are declared for descriptive purposes only and go out of scope at the end of the declaration of **apfi**.

3. The declaration

```
int (*fpfi(int (*)(long), int))(int, ...);
```

declares a function **fpfi** that returns a pointer to a function returning an **int**. The function **fpfi** has two parameters: a pointer to a function returning an **int** (with one parameter of type **long**), and an **int**. The pointer returned by **fpfi** points to a function that has one **int** parameter and accepts zero or more additional arguments of any type.

Forward references: function definitions (6.7.1), type names (6.5.5).

6.5.5 Type names

Syntax

[1]

type-name:
    specifier-qualifier-list abstract-declarator$_{opt}$

abstract-declarator:
    pointer
    pointer$_{opt}$ *direct-abstract-declarator*

direct-abstract-declarator:
    (*abstract-declarator* **)**
    direct-abstract-declarator$_{opt}$ **[** *constant-expression*$_{opt}$ **]**
    direct-abstract-declarator$_{opt}$ **(** *parameter-type-list*$_{opt}$ **)**

Semantics

[2] In several contexts, it is desired to specify a type. This is accomplished using a *type name*, which is syntactically a declaration for a function or an object of that type that omits the identifier.[82]

Example

[3] The constructions

```
(a)  int
(b)  int *
(c)  int *[3]
(d)  int (*)[3]
(e)  int *()
(f)  int (*)(void)
(g)  int (*const [])(unsigned int, ...)
```

name respectively the types (a) **int**, (b) pointer to **int**, (c) array of three pointers to **int**, (d) pointer to an array of three **int**s, (e) function with no parameter specification returning a pointer to **int**, (f) pointer to function with no parameters returning an **int**, and (g) array of an unspecified number of constant pointers to functions, each with one parameter that has type **unsigned int** and an unspecified number of other parameters, returning an **int**.

6.5.6 Type definitions

Syntax

[1]

typedef-name:
  identifier

Semantics

[2] In a declaration whose storage-class specifier is **typedef**, each declarator defines an identifier to be a typedef name that specifies the type specified for the identifier in the way described in 6.5.4. A **typedef** declaration does not introduce a new type, only a synonym for the type so specified. That is, in the following declarations:

```
typedef T type_ident;
type_ident D;
```

type_ident is defined as a typedef name with the type specified by the declaration specifiers in **T** (known as *T*), and the identifier in **D** has the type ‘‘*derived-declarator-type-list T*’’ where the *derived-declarator-type-list* is specified by the declarators of **D**.

---

82. As indicated by the syntax, empty parentheses in a type name are interpreted as ‘‘function with no parameter specification,’’ rather than redundant parentheses around the omitted identifier.

A typedef name shares the same name space as other identifiers declared in ordinary declarators. If the identifier is redeclared in an inner scope or is declared as a member of a structure or union in the same or an inner scope, the type specifiers shall not be omitted in the inner declaration.

Examples

[3]

1. After

```
typedef int MILES, KLICKSP();
typedef struct { double hi, lo; } range;
```

the constructions

```
MILES distance;
extern KLICKSP *metricp;
range x;
range z, *zp;
```

are all valid declarations. The type of **distance** is **int**, that of **metricp** is ‘‘pointer to function with no parameter specification returning **int**,’’ and that of **x** and **z** is the specified structure; **zp** is a pointer to such a structure. The object **distance** has a type compatible with any other **int** object.

2. After the declarations

```
typedef struct s1 { int x; } t1, *tp1;
typedef struct s2 { int x; } t2, *tp2;
```

type **t1** and the type pointed to by **tp1** are compatible. Type **t1** is also compatible with type **struct s1**, but not compatible with the types **struct s2**, **t2**, the type pointed to by **tp2**, and **int**.

3. The following obscure constructions

```
typedef signed int t;
typedef int plain;
struct tag {
     unsigned t:4;
     const t:5;
     plain r:5;
};
```

declare a typedef name **t** with type **signed int**, a typedef name **plain** with type **int**, and a structure with three bit-field members, one named **t** that contains values in the range [0,15], an unnamed const-qualified bit-field which (if it could be accessed) would contain values in at least the range [−15,+15], and one named **r** that contains values in the range [0,31] or values in at least the range [−15,+15]. (The choice of range is implementation-defined.) The first two bit-field declarations differ in that **unsigned** is a type specifier (which forces **`t`** to be the name of a structure member), while **`const`** is a type qualifier (which modifies **`t`** which is still visible as a typedef name). If these declarations are followed in an inner scope by

```
t f(t (t));
long t;
```

then a function **`f`** is declared with type ‘‘function returning **`signed int`** with one unnamed parameter with type pointer to function returning **`signed int`** with one unnamed parameter with type **`signed int`**,’’ and an identifier **`t`** with type **`long`**.

4. On the other hand, typedef names can be used to improve code readability. All three of the following declarations of the **`signal`** function specify exactly the same type, the first without making use of any typedef names.

```
typedef void fv(int), (*pfv)(int);

void (*signal(int, void (*)(int)))(int);
fv *signal(int, fv *);
pfv signal(int, pfv);
```

Forward references: the **`signal`** function (7.9.1.1).

6.5.7 Initialization

Syntax

[1]

initializer:
  assignment-expression
  `{` *initializer-list* **`}`**
  `{` *initializer-list* **`, }`**

initializer-list:
  designation-opt initializer
  initializer-list **`,`** *designation-opt initializer*

designation:
  designator-list **`=`**

designator-list:
  designator
  designator-list designator

designator:
  `[` *constant-expression* **`]`**
  `.` *identifier*

Constraints

[2] There shall be no more initializers in an initializer list than there are objects to be initialized.

[3] The type of the entity to be initialized shall be an object type or an array of unknown size.

[4] All the expressions in an initializer for an object that has static storage duration or in an initializer list for an object that has aggregate or union type shall be constant expressions.

[5] If the declaration of an identifier has block scope, and the identifier has external or internal linkage, the declaration shall have no initializer for the identifier.

[6] No initializer shall attempt to provide a value for an object not contained within the entity being initialized. If a designator has the form

[*constant-expression* **]**

then the *current object* (defined below) shall have array type and the expression shall be an integral constant expression. If the array is of unknown size, any nonnegative value is valid.

[7] If a designator has the form

. *identifier*

then the current object (defined below) shall have structure or union type and the identifier shall be a member of that type.

Semantics

[8] An initializer specifies the initial value stored in an object.

[9] Except where explicitly stated otherwise, for the purposes of this subclause unnamed members of objects of structure and union type do not participate in initialization. Unnamed members of structure objects have indeterminate value even after initialization. A union object containing only unnamed members has indeterminate value even after initialization.

[10] If an object that has automatic storage duration is not initialized explicitly, its value is indeterminate.[83] If an object that has static storage duration is not initialized explicitly, then:

— if it has pointer type, it is initialized to a null pointer;

— if it has arithmetic type, it is initialized to zero;

— if it is an aggregate, every member is initialized (recursively) according to these rules;

83. Unlike in the base document, any automatic duration object may be initialized.

— if it is a union, the first named member is initialized (recursively) according to these rules.

[11] The initializer for a scalar shall be a single expression, optionally enclosed in braces. The initial value of the object, including unnamed members, is that of the expression; the same type constraints and conversions as for simple assignment apply, taking the type of the scalar to be the unqualified version of its declared type.

[12] Each brace-enclosed initializer list has an associated current object. When no designations are present, subobject of the current object are initialized in order according to the type of the current object: array elements in increasing subscript order, structure members in declaration order, and the first member of a union.[84] In contrast, a designation causes the following initializer to begin initialization of the subobject described by the designator. Initialization then continues forward in order, beginning with the next subobject after that described by the designator.[85]

[13] Each designator list begins its description with the current object associated with the closest surrounding brace pair. Each item in the designator list (in order) specifies a particular member of its current object and changes the current object for the next designator (if any) to be that member.[86] The current object that results at the end of the designator list is the subobject to be initialized by the following initializer.

[14] The initialization shall occur in initializer list order, each initializer provided for a particular subobject overriding any previously listed initializer for the same subobject; all subobjects that are not initialized explicitly shall be initialized implicitly the same as objects that have static storage duration.

[15] If an array of unknown size is initialized, its size is determined by the largest indexed element with an explicit initializer.

[16] The initializer for a structure or union object that has automatic storage duration either shall be an initializer list as described below, or shall be a single expression that has compatible structure or union type. In the latter case, the initial value of the object is that of the expression.

[17] The rest of this subclause deals with initializers for objects that have aggregate or union type.

84. If the initializer list for a subaggregate or contained union does not begin with a left brace, its subobjects are initialized as usual, but the subaggregate or contained union does not become the current object: current objects are associated only with brace-enclosed initializer lists.

85. After a union member is initialized, the next object is not the next member of the union; instead, it is the next subobject of an object containing the union.

86. Thus, a designator can only specify a strict subobject of the aggregate or union that is associated with the surrounding brace pair. Note, too, that each separate designator list is independent.

[18] An array of character type may be initialized by a character string literal, optionally enclosed in braces. Successive characters of the character string literal (including the terminating null character if there is room or if the array is of unknown size) initialize the elements of the array.

[19] An array with element type compatible with **`wchar_t`** may be initialized by a wide string literal, optionally enclosed in braces. Successive codes of the wide string literal (including the terminating zero-valued code if there is room or if the array is of unknown size) initialize the elements of the array.

[20] Otherwise, the initializer for an object that has aggregate type shall be a brace-enclosed list of initializers for the members of the aggregate, written in increasing subscript or member order; and the initializer for an object that has union type shall be a brace-enclosed initializer for the first member of the union.

[21] If the aggregate contains members that are aggregates or unions, or if the first member of a union is an aggregate or union, the rules apply recursively to the subaggregates or contained unions. If the initializer of a subaggregate or contained union begins with a left brace, the initializers enclosed by that brace and its matching right brace initialize the members of the subaggregate or the first member of the contained union. Otherwise, only enough initializers from the list are taken to account for the members of the subaggregate or the first member of the contained union; any remaining initializers are left to initialize the next member of the aggregate of which the current subaggregate or contained union is a part.

[22] If there are fewer initializers in a brace-enclosed list than there are members of an aggregate, or fewer characters in a string literal or wide string literal used to initialize an array of known size, and elements of character or **`wchar_t`** type, the remainder of the aggregate shall be initialized implicitly the same as objects that have static storage duration.

[23] If an array of unknown size is initialized, its size is determined by the number of initializers provided for its elements. At the end of its initializer list, the array no longer has incomplete type.

Examples

[24]

1. The declaration

```
int x[] = { 1, 3, 5 };
```

   defines and initializes **`x`** as a one-dimensional array object that has three elements, as no size was specified and there are three initializers.

2. The declaration

```
float y[4][3] = {
     { 1, 3, 5 },
     { 2, 4, 6 },
     { 3, 5, 7 },
};
```

is a definition with a fully bracketed initialization: 1, 3, and 5 initialize the first row of **y** (the array object **y[0]**), namely **y[0][0]**, **y[0][1]**, and **y[0][2]**. Likewise the next two lines initialize **y[1]** and **y[2]**. The initializer ends early, so **y[3]** is initialized with zeros. Precisely the same effect could have been achieved by

```
float y[4][3] = {
     1, 3, 5, 2, 4, 6, 3, 5, 7
};
```

The initializer for **y[0]** does not begin with a left brace, so three items from the list are used. Likewise the next three are taken successively for **y[1]** and **y[2]**.

3. The declaration

```
float z[4][3] = {
     { 1 }, { 2 }, { 3 }, { 4 }
};
```

initializes the first column of **z** as specified and initializes the rest with zeros.

4. The declaration

```
struct { int a[3], b; } w[] = { { 1 }, 2 };
```

is a definition with an inconsistently bracketed initialization. It defines an array with two element structures: **w[0].a[0]** is 1 and **w[1].a[0]** is 2; all the other elements are zero.

5. The declaration

```
short q[4][3][2] = {
     { 1 },
     { 2, 3 },
     { 4, 5, 6 }
};
```

contains an incompletely but consistently bracketed initialization. It defines a three-dimensional array object: **q[0][0][0]** is 1, **q[1][0][0]** is 2, **q[1][0][1]** is 3, and 4, 5, and 6 initialize **q[2][0][0]**, **q[2][0][1]**, and **q[2][1][0]**, respectively; all the rest are zero. The initializer for **q[0][0]** does not begin with a left brace, so up to six items from the current list may be used. There is only one, so the values for the remaining five elements are initialized with zero. Likewise, the initializers for **q[1][0]** and **q[2][0]** do not begin with a left brace, so each uses up to six items, initializing their respective two-dimensional subaggregates. If there had been more than six items in any of the lists, a diagnostic message would have been issued. The same initialization result could have been achieved by:

```
short q[4][3][2] = {
     1, 0, 0, 0, 0, 0,
     2, 3, 0, 0, 0, 0,
     4, 5, 6
};
```

or by:

```
short q[4][3][2] = {
     {
          { 1 },
     },
     {
          { 2, 3 },
     },
     {
          { 4, 5 },
          { 6 },
     }
};
```

in a fully bracketed form.

Note that the fully bracketed and minimally bracketed forms of initialization are, in general, less likely to cause confusion.

6. One form of initialization that completes array types involves typedef names. Given the declaration

```
typedef int A[];
```

the declaration

```
A a = {1, 2}, b = {3, 4, 5};
```

is identical to

```
int a[] = {1, 2}, b[] = {3, 4, 5};
```

due to the rules for incomplete types.

7. The declaration

```
char s[] = "abc", t[3] = "abc";
```

defines ‘‘plain’’ **char** array objects **s** and **t** whose elements are initialized with character string literals. This declaration is identical to

```
char s[] = { 'a', 'b', 'c', '\0' },
     t[] = { 'a', 'b', 'c' };
```

The contents of the arrays are modifiable. On the other hand, the declaration

```
char *p = "abc";
```

defines **p** with type ''pointer to **char**'' that is initialized to point to an object with type ''array of **char**'' with length 4 whose elements are initialized with a character string literal. If an attempt is made to use **p** to modify the contents of the array, the behavior is undefined.

8. Arrays can be initialized to correspond to the elements of an enumeration by using designators:

```
   enum { member_one, member_to, /* ... */ };
   const char *nm[] =
   {
           [member_two] = "member two",
           [member_one] = "member one",
           /* ... */
};
```

9. Structure members can be initialized to nonzero values without depending on their order:

```
   div_t answer = { .quot = 2, .rem = -1 };
```

10. Designators can be used to provide explicit initialization when unadorned initializer lists might be misunderstood:

```
struct { init a[3], b; } w[] =
    { [0].a = {1}, [1].a[0] = 2 };
```

11. Space can be ''allocated'' from both ends of an array by using a single designator:

```
int a[MAX] =
{
    1, 3, 5, 7, 9, [MAX-5] = 8, 6, 4, 2, 0
};
```

In the above, if **MAX** is greater than ten, there will be some zero-valued elements in the middle; if it is less than ten, some of the values provided by the first five initializers will be overridden by the second five.

12. Any member of a union can be initialized:

```
union { /* ... */ } u = { .any_member = 42 };
```

Forward references: common definitions **<stddef.h>** (7.1.5).

6.6 Statements

Syntax

[1]

statement:
labeled-statement
compound-statement
expression-statement
selection-statement
iteration-statement
jump-statement

Semantics

[2] A *statement* specifies an action to be performed. Except as indicated, statements are executed in sequence.

[3] A *full expression* is an expression that is not part of another expression. Each of the following is a full expression: an initializer; the expression in an expression statement; the controlling expression of a selection statement (**`if`** or **`switch`**); the controlling expression of a **`while`** or **`do`** statement; each of the three (optional) expressions of a **`for`** statement; the (optional) expression in a **`return`** statement. The end of a full expression is a sequence point.

Forward references: expression and null statements (6.6.3), selection statements (6.6.4), iteration statements (6.6.5), the **`return`** statement (6.6.6.4).

6.6.1 Labeled statements

Syntax

[1]

labeled-statement:
identifier **`:`** *statement*
`case` *constant-expression* **`:`** *statement*
`default :` *statement*

Constraints

[2] A **`case`** or **`default`** label shall appear only in a **`switch`** statement. Further constraints on such labels are discussed under the **`switch`** statement.

Semantics

[3] Any statement may be preceded by a prefix that declares an identifier as a label name. Labels in themselves do not alter the flow of control, which continues unimpeded across them.

Forward references: the **`goto`** statement (6.6.6.1), the **`switch`** statement (6.6.4.2).

6.6.2 Compound statement, or block

Syntax

[1]

compound-statement:
  { *declaration-list*$_{opt}$ *statement-list*$_{opt}$ **}**

declaration-list:
  declaration
  declaration-list declaration

statement-list:
  statement
  statement-list statement

Semantics

[2] A *compound statement* (also called a *block*) allows a set of statements to be grouped into one syntactic unit, which may have its own set of declarations and initializations (as discussed in 6.1.2.4). The initializers of objects that have automatic storage duration are evaluated and the values are stored in the objects in the order their declarators appear in the translation unit.

6.6.3 Expression and null statements

Syntax

[1]

expression-statement:
  expression$_{opt}$ **;**

Semantics

[2] The expression in an expression statement is evaluated as a void expression for its side effects.[87]

[3] A *null statement* (consisting of just a semicolon) performs no operations.

Examples

[4]

1. If a function call is evaluated as an expression statement for its side effects only, the discarding of its value may be made explicit by converting the expression to

87. Such as assignments, and function calls which have side effects.

a void expression by means of a cast:

```
int p(int);
/*...*/
(void)p(0);
```

2. In the program fragment

```
char *s;
/*...*/
while (*s++ != '\0')
     ;
```

a null statement is used to supply an empty loop body to the iteration statement.

3. A null statement may also be used to carry a label just before the closing **}** of a compound statement.

```
while (loop1) {
     /*...*/
     while (loop2) {
          /*...*/
          if (want_out)
               goto end_loop1;
          /*...*/
     }
     /*...*/
end_loop1: ;
}
```

Forward references: iteration statements (6.6.5).

6.6.4 Selection statements

Syntax

[1]

selection-statement:
  if (*expression* **)** *statement*
  if (*expression* **)** *statement* **else** *statement*
  switch (*expression* **)** *statement*

Semantics

[2] A selection statement selects among a set of statements depending on the value of a controlling expression.

6.6.4.1 The `if` statement

Constraints

[1] The controlling expression of an **`if`** statement shall have scalar type.

Semantics

[2] In both forms, the first substatement is executed if the expression compares unequal to 0. In the **`else`** form, the second substatement is executed if the expression compares equal to 0. If the first substatement is reached via a label, the second substatement is not executed.

[3] An **`else`** is associated with the lexically immediately preceding **`else`**-less **`if`** that is in the same block (but not in an enclosed block).

6.6.4.2 The `switch` statement

Constraints

[1] The controlling expression of a **`switch`** statement shall have integral type. The expression of each **`case`** label shall be an integral constant expression. No two of the **`case`** constant expressions in the same **`switch`** statement shall have the same value after conversion. There may be at most one **`default`** label in a **`switch`** statement. (Any enclosed **`switch`** statement may have a **`default`** label or **`case`** constant expressions with values that duplicate **`case`** constant expressions in the enclosing **`switch`** statement.)

Semantics

[2] A **`switch`** statement causes control to jump to, into, or past the statement that is the *switch body*, depending on the value of a controlling expression, and on the presence of a **`default`** label and the values of any **`case`** labels on or in the switch body. A **`case`** or **`default`** label is accessible only within the closest enclosing **`switch`** statement.

[3] The integral promotions are performed on the controlling expression. The constant expression in each **`case`** label is converted to the promoted type of the controlling expression. If a converted value matches that of the promoted controlling expression, control jumps to the statement following the matched **`case`** label. Otherwise, if there is a **`default`** label, control jumps to the labeled statement. If no converted **`case`** constant expression matches and there is no **`default`** label, no part of the switch body is executed.

Implementation limits

[4] As discussed previously (5.2.4.1), the implementation may limit the number of **`case`** values in a **`switch`** statement.

Example

[5] In the artificial program fragment

```
switch (expr)
{
     int i = 4;
     f(i);
case 0:
     i = 17;    /* falls through into default code */
default:
     printf("%d\n", i);
}
```

the object whose identifier is **i** exists with automatic storage duration (within the block) but is never initialized, and thus if the controlling expression has a nonzero value, the call to the **printf** function will access an indeterminate value. Similarly, the call to the function **f** cannot be reached.

6.6.5 Iteration statements

Syntax

[1]

iteration-statement:
  while (*expression* **)** *statement*
  do *statement* **while (** *expression* **) ;**
  for (*expression*$_{opt}$ **;** *expression*$_{opt}$ **;** *expression*$_{opt}$ **)** *statement*

Constraints

[2] The controlling expression of an iteration statement shall have scalar type.

Semantics

[3] An iteration statement causes a statement called the *loop body* to be executed repeatedly until the controlling expression compares equal to 0.

6.6.5.1 The while statement

[1] The evaluation of the controlling expression takes place before each execution of the loop body.

6.6.5.2 The do statement

[1] The evaluation of the controlling expression takes place after each execution of the loop body.

6.6.5.3 The for statement

[1] Except for the behavior of a **continue** statement in the loop body, the statement

  for (*expression-1* **;** *expression-2* **;** *expression-3* **)** *statement*

and the sequence of statements

```
expression-1 ;
while ( expression-2 ) {
        statement
        expression-3 ;
}
```

are equivalent.[88]

[2] Both *expression-1* and *expression-3* may be omitted. Each is evaluated as a void expression. An omitted *expression-2* is replaced by a nonzero constant.

Forward references: the **`continue`** statement (6.6.6.2).

6.6.6 Jump statements

Syntax

[1]

```
jump-statement:
        goto identifier ;
        continue ;
        break ;
        return expression_opt ;
```

Semantics

[2] A jump statement causes an unconditional jump to another place.

6.6.6.1 The `goto` statement

Constraints

[1] The identifier in a **`goto`** statement shall name a label located somewhere in the enclosing function.

Semantics

A **`goto`** statement causes an unconditional jump to the statement prefixed by the named label in the enclosing function.

Example

[2] It is sometimes convenient to jump into the middle of a complicated set of statements. The following outline presents one possible approach to a problem based on these three assumptions:

88. Thus, *expression-1* specifies initialization for the loop; *expression-2*, the controlling expression, specifies an evaluation made before each iteration, such that execution of the loop continues until the expression compares equal to 0; *expression-3* specifies an operation (such as incrementing) that is performed after each iteration.

1. The general initialization code accesses objects only visible to the current function.
2. The general initialization code is too large to warrant duplication.
3. The code to determine the next operation must be at the head of the loop. (To allow it to be reached by **`continue`** statements, for example.)

```
/*...*/
goto first_time;
for (;;) {
        /* determine next operation */
        /*...*/
        if (need to reinitialize) {
                /* reinitialize-only code */
                /*...*/
        first_time:
                /* general initialization code */
                /*...*/
                continue;
        }
        /* handle other operations */
        /*...*/
}
```

6.6.6.2 The `continue` statement

Constraints

[1] A **`continue`** statement shall appear only in or as a loop body.

Semantics

[2] A **`continue`** statement causes a jump to the loop-continuation portion of the smallest enclosing iteration statement; that is, to the end of the loop body. More precisely, in each of the statements

```
while (/*...*/) {  do {                for (/*...*/) {
  /*...*/            /*...*/              /*...*/
  continue;          continue;            continue;
  /*...*/            /*...*/              /*...*/
contin: ;          contin: ;           contin: ;
}                  } while (/*...*/); }
```

unless the **`continue`** statement shown is in an enclosed iteration statement (in which case it is interpreted within that statement), it is equivalent to **`goto contin;`**.[89]

6.6.6.3 The `break` statement

Constraints

[1] A **`break`** statement shall appear only in or as a switch body or loop body.

Semantics

[2] A **`break`** statement terminates execution of the smallest enclosing **`switch`** or iteration statement.

6.6.6.4 The `return` statement

Constraints

[1] A **`return`** statement with an expression shall not appear in a function whose return type is **`void`**.

Semantics

[2] A **`return`** statement terminates execution of the current function and returns control to its caller. A function may have any number of **`return`** statements, with and without expressions.

[3] If a **`return`** statement with an expression is executed, the value of the expression is returned to the caller as the value of the function call expression. If the expression * has a type different from the return type of the function in which it appears, the value is converted as if by assignment to an object having the return type of the function.[90]

[4] If a **`return`** statement without an expression is executed, and the value of the function call is used by the caller, the behavior is undefined. Reaching the **`}`** that terminates a function is equivalent to executing a **`return`** statement without an expression.

Example

[5] In: *

---

89. Following the **`contin:`** label is a null statement.

90. The **`return`** statement is not an assignment. The overlap restriction of subclause 6.3.16.1 does not apply to the case of function return.

```
struct s { double i; } f(void);
union {
     struct {
          int f1;
          struct s f2;
     } u1;
     struct {
          struct s f3;
          int f4;
     } u2;
} g;

struct s f(void)
{
     return g.u1.f2;
}

/* ... */
g.u2.f3 = f();
```

the behavior is defined.

6.7 External definitions

Syntax

[1]

translation-unit:
  external-declaration
  translation-unit external-declaration

external-declaration:
  function-definition
  declaration

Constraints

[2] The storage-class specifiers **`auto`** and **`register`** shall not appear in the declaration specifiers in an external declaration.

[3] There shall be no more than one external definition for each identifier declared with internal linkage in a translation unit. Moreover, if an identifier declared with internal linkage is used in an expression (other than as a part of the operand of a **`sizeof`** operator), there shall be exactly one external definition for the identifier in the translation unit.

Semantics

[4] As discussed in 5.1.1.1, the unit of program text after preprocessing is a translation unit, which consists of a sequence of external declarations. These are described as ‘‘external’’ because they appear outside any function (and hence have file scope). As discussed in 6.5, a declaration that also causes storage to be reserved for an object or a function named by the identifier is a definition.

[5] An *external definition* is an external declaration that is also a definition of a function or an object. If an identifier declared with external linkage is used in an expression (other than as part of the operand of a **`sizeof`** operator), somewhere in the entire program there shall be exactly one external definition for the identifier; otherwise, there shall be no more than one.[91]

91. Thus, if an identifier declared with external linkage is not used in an expression, there need be no external definition for it.

6.7.1 Function definitions

Syntax

[1]

function-definition:
    declaration-specifiers$_{opt}$ *declarator* *declaration-list*$_{opt}$ *compound-statement*

Constraints

[2] The identifier declared in a function definition (which is the name of the function) shall have a function type, as specified by the declarator portion of the function definition.[92]

[3] The return type of a function shall be **`void`** or an object type other than array.

[4] The storage-class specifier, if any, in the declaration specifiers shall be either **`extern`** or **`static`**.

[5] If the declarator includes a parameter type list, the declaration of each parameter shall include an identifier (except for the special case of a parameter list consisting of a single parameter of type **`void`**, in which there shall not be an identifier). No declaration list shall follow.

[6] If the declarator includes an identifier list, each declaration in the declaration list shall have at least one declarator, and those declarators shall declare only identifiers from the identifier list. An identifier declared as a typedef name shall not be redeclared as a parameter. The declarations in the declaration list shall contain no storage-class specifier other than **`register`** and no initializations.

Semantics

[7] The declarator in a function definition specifies the name of the function being defined and the identifiers of its parameters. If the declarator includes a parameter type list, the list also specifies the types of all the parameters; such a declarator also serves as a function prototype for later calls to the same function in the same

---

92. The intent is that the type category in a function definition cannot be inherited from a typedef:

```
typedef int F(void);          /* type F is ‘‘function of no arguments returning int’’ */
F f, g;                       /* f and g both have type compatible with F */
F f { /*...*/ }               /* WRONG: syntax/constraint error */
F g() { /*...*/ }             /* WRONG: declares that g returns a function */
int f(void) { /*...*/ }       /* RIGHT: f has type compatible with F */
int g() { /*...*/ }           /* RIGHT: g has type compatible with F */
F *e(void) { /*...*/ }        /* e returns a pointer to a function */
F *((e))(void) { /*...*/ }    /* same: parentheses irrelevant */
int (*fp)(void);              /* fp points to a function that has type F */
F *Fp;                        /* Fp points to a function that has type F */
```

translation unit. If the declarator includes an identifier list,[93] the types of the parameters may be declared in a following declaration list. Any parameter that is not declared has type **`int`**.

[8] If a function that accepts a variable number of arguments is defined without a parameter type list that ends with the ellipsis notation, the behavior is undefined.

[9] On entry to the function the value of each argument expression shall be converted to the type of its corresponding parameter, as if by assignment to the parameter. Array expressions and function designators as arguments are converted to pointers before the call. A declaration of a parameter as ''array of *type*'' shall be adjusted to ''pointer to *type*,'' and a declaration of a parameter as ''function returning *type*'' shall be adjusted to ''pointer to function returning *type*,'' as in 6.2.2.1. The resulting parameter type shall be an object type.

[10] Each parameter has automatic storage duration. Its identifier is an lvalue.[94] The layout of the storage for parameters is unspecified.

Examples

[11]

1. In the following:

```
extern int max(int a, int b)
{
        return a > b ? a : b;
}
```

`extern` is the storage-class specifier and **`int`** is the type specifier (each of which may be omitted as those are the defaults); **`max(int a, int b)`** is the function declarator; and

```
{ return a > b ? a : b; }
```

is the function body. The following similar definition uses the identifier-list form for the parameter declarations:

```
extern int max(a, b)
int a, b;
{
        return a > b ? a : b;
}
```

93. See ''future language directions'' (6.9.5).

94. A parameter is in effect declared at the head of the compound statement that constitutes the function body, and therefore may not be redeclared in the function body (except in an enclosed block).

Here **int a, b;** is the declaration list for the parameters, which may be omitted because those are the defaults. The difference between these two definitions is that the first form acts as a prototype declaration that forces conversion of the arguments of subsequent calls to the function, whereas the second form may not.

2. To pass one function to another, one might say

```
int f(void);
/*...*/
g(f);
```

Note that **f** must be declared explicitly in the calling function, as its appearance in the expression **g(f)** was not followed by **(**. Then the definition of **g** might read

```
g(int (*funcp)(void))
{
     /*...*/ (*funcp)() /* or funcp() ... */
}
```

or, equivalently,

```
g(int func(void))
{
     /*...*/ func() /* or (*func)() ... */
}
```

6.7.2 External object definitions

Semantics

[1] If the declaration of an identifier for an object has file scope and an initializer, the declaration is an external definition for the identifier.

[2] A declaration of an identifier for an object that has file scope without an initializer, and without a storage-class specifier or with the storage-class specifier **static**, constitutes a *tentative definition*. If a translation unit contains one or more tentative definitions for an identifier, and the translation unit contains no external definition for that identifier, then the behavior is exactly as if the translation unit contains a file scope declaration of that identifier, with the composite type as of the end of the translation unit, with an initializer equal to 0.

[3] If the declaration of an identifier for an object is a tentative definition and has internal linkage, the declared type shall not be an incomplete type.

Example

[4]

1.

```
int i1 = 1;                /* definition, external linkage */
static int i2 = 2;   /* definition, internal linkage */
extern int i3 = 3;   /* definition, external linkage */
int i4;                    /* tentative definition, external linkage */
static int i5;             /* tentative definition, internal linkage */

int i1;          /* valid tentative definition, refers to previous */
int i2;          /* 6.1.2.2 renders undefined, linkage disagreement */
int i3;          /* valid tentative definition, refers to previous */
int i4;          /* valid tentative definition, refers to previous */
int i5;          /* 6.1.2.2 renders undefined, linkage disagreement */

extern int i1; /* refers to previous, whose linkage is external */
extern int i2; /* refers to previous, whose linkage is internal */
extern int i3; /* refers to previous, whose linkage is external */
extern int i4; /* refers to previous, whose linkage is external */
extern int i5; /* refers to previous, whose linkage is internal */
```

2. If at the end of the translation unit containing *

```
int i[];
```

the array **i** still has incomplete type, the array is assumed to have one element. This element is initialized to zero on program startup.

6.8 Preprocessing directives

Syntax

[1]

preprocessing-file:
  group$_{opt}$

group:
  group-part
  group group-part

group-part:
  pp-tokens$_{opt}$ *new-line*
  if-section
  control-line

if-section:
  if-group elif-groups$_{opt}$ *else-group*$_{opt}$ *endif-line*

if-group:
  # if *constant-expression new-line group*$_{opt}$
  # ifdef *identifier new-line group*$_{opt}$
  # ifndef *identifier new-line group*$_{opt}$

elif-groups:
  elif-group
  elif-groups elif-group

elif-group:
  # elif *constant-expression new-line group*$_{opt}$

else-group:
  # else *new-line group*$_{opt}$

endif-line:
  # endif *new-line*

control-line:
  # include *pp-tokens new-line*
  # define *identifier replacement-list new-line*
  # define *identifier lparen identifier-list*$_{opt}$ **)** *replacement-list new-line*
  # undef *identifier new-line*
  # line *pp-tokens new-line*
  # error *pp-tokens*$_{opt}$ *new-line*
  # pragma *pp-tokens*$_{opt}$ *new-line*
  # *new-line*

lparen:
  the left-parenthesis character without preceding white-space

replacement-list:
  pp-tokens$_{opt}$

pp-tokens:
  preprocessing-token
  pp-tokens preprocessing-token

new-line:
  the new-line character

Description

[2] A preprocessing directive consists of a sequence of preprocessing tokens that begins with a **#** preprocessing token that is either the first character in the source file (optionally after white space containing no new-line characters) or that follows white space containing at least one new-line character, and is ended by the next new-line character.[95] A new-line character ends the preprocessing directive even if it occurs within what would otherwise be an invocation of a function-like macro. *

Constraints

[3] The only white-space characters that shall appear between preprocessing tokens within a preprocessing directive (from just after the introducing **#** preprocessing token through just before the terminating new-line character) are space and horizontal-tab (including spaces that have replaced comments or possibly other white-space characters in translation phase 3).

[4] In the definition of an object-like macro, if the first character of a replacement list is not a character required by subclause 5.2.1, then there shall be white-space separation between the identifier and the replacement list.[96] *

Semantics

[5] The implementation can process and skip sections of source files conditionally, include other source files, and replace macros. These capabilities are called *preprocessing*, because conceptually they occur before translation of the resulting translation unit.

[6] The preprocessing tokens within a preprocessing directive are not subject to macro expansion unless otherwise stated.

---

95. Thus, preprocessing directives are commonly called ‘‘lines.’’ These ‘‘lines’’ have no other syntactic significance, as all white space is equivalent except in certain situations during preprocessing (see the **#** character string literal creation operator in 6.8.3.2, for example).

96. This allows an implementation to choose to interpret the directive:
```
#define THIS$AND$THAT(a, b)   ((a) + (b))
```
as defining a function-like macro **THISANDTHAT**, rather than an object-like macro **THIS**. Whichever choice it makes, it must also issue a diagnostic.

6.8.1 Conditional inclusion

Constraints

[1] The expression that controls conditional inclusion shall be an integral constant expression except that: it shall not contain a cast; identifiers (including those lexically identical to keywords) are interpreted as described below;[97] and it may contain unary operator expressions of the form

`defined` *identifier*

or

`defined (` *identifier* **`)`**

which evaluate to 1 if the identifier is currently defined as a macro name (that is, if it is predefined or if it has been the subject of a **`#define`** preprocessing directive without an intervening **`#undef`** directive with the same subject identifier), 0 if it is not.

[2] Each preprocessing token that remains after all macro replacements have occurred shall be in the lexical form of a token.

Semantics

[3] Preprocessing directives of the forms

`# if` *constant-expression new-line group*$_{opt}$
`# elif` *constant-expression new-line group*$_{opt}$

check whether the controlling constant expression evaluates to nonzero.

[4] Prior to evaluation, macro invocations in the list of preprocessing tokens that will become the controlling constant expression are replaced (except for those macro names modified by the **`defined`** unary operator), just as in normal text. If the token **`defined`** is generated as a result of this replacement process or use of the **`defined`** unary operator does not match one of the two specified forms prior to macro replacement, the behavior is undefined. After all replacements due to macro expansion and the **`defined`** unary operator have been performed, all remaining identifiers are replaced with the pp-number **`0`**, and then each preprocessing token is converted into a token. The resulting tokens comprise the controlling constant expression which is evaluated according to the rules of 6.4 using arithmetic that has at least the ranges specified in 5.2.4.2, except that **`int`** and **`long`**, and **`unsigned int`** and **`unsigned long`**, act as if they have the same representation as, respectively, **`long long`** and **`unsigned long long`**. This includes interpreting character constants, which may involve converting escape sequences into execution character set members. Whether

97. Because the controlling constant expression is evaluated during translation phase 4, all identifiers either are or are not macro names — there simply are no keywords, enumeration constants, etc.

the numeric value for these character constants matches the value obtained when an identical character constant occurs in an expression (other than within a **#if** or **#elif** directive) is implementation-defined.[98] Also, whether a single-character character constant may have a negative value is implementation-defined.

[5] Preprocessing directives of the forms

> **# ifdef** *identifier new-line group$_{opt}$*
> **# ifndef** *identifier new-line group$_{opt}$*

check whether the identifier is or is not currently defined as a macro name. Their conditions are equivalent to **#if defined** *identifier* and **#if !defined** *identifier* respectively.

[6] Each directive's condition is checked in order. If it evaluates to false (zero), the group that it controls is skipped: directives are processed only through the name that determines the directive in order to keep track of the level of nested conditionals; the rest of the directives' preprocessing tokens are ignored, as are the other preprocessing tokens in the group. Only the first group whose control condition evaluates to true (nonzero) is processed. If none of the conditions evaluates to true, and there is a **#else** directive, the group controlled by the **#else** is processed; lacking a **#else** directive, all the groups until the **#endif** are skipped.[99]

Forward references: macro replacement (6.8.3), source file inclusion (6.8.2).

6.8.2 Source file inclusion

Constraints

[1] A **#include** directive shall identify a header or source file that can be processed by the implementation.

Semantics

[2] A preprocessing directive of the form

> **# include <**<*h-char-sequence*>**>** *new-line*

searches a sequence of implementation-defined places for a header identified uniquely by the specified sequence between the **<** and **>** delimiters, and causes the replacement

---

98. Thus, the constant expression in the following **#if** directive and **if** statement is not guaranteed to evaluate to the same value in these two contexts.

```
#if 'z' - 'a' == 25
if ('z' - 'a' == 25)
```

99. As indicated by the syntax, a preprocessing token shall not follow a **#else** or **#endif** directive before the terminating new-line character. However, comments may appear anywhere in a source file, including within a preprocessing directive.

of that directive by the entire contents of the header. How the places are specified or the header identified is implementation-defined.

[3] A preprocessing directive of the form

`# include "`*q-char-sequence***`"`** *new-line*

causes the replacement of that directive by the entire contents of the source file identified by the specified sequence between the **`"`** delimiters. The named source file is searched for in an implementation-defined manner. If this search is not supported, or if the search fails, the directive is reprocessed as if it read

`# include <`*h-char-sequence***`>`** *new-line*

with the identical contained sequence (including **`>`** characters, if any) from the original directive.

[4] A preprocessing directive of the form

`# include` *pp-tokens new-line*

(that does not match one of the two previous forms) is permitted. The preprocessing tokens after **`include`** in the directive are processed just as in normal text. (Each identifier currently defined as a macro name is replaced by its replacement list of preprocessing tokens.) The directive resulting after all replacements shall match one of the two previous forms.[100] The method by which a sequence of preprocessing tokens between a **`<`** and a **`>`** preprocessing token pair or a pair of **`"`** characters is combined into a single header name preprocessing token is implementation-defined.

[5] There shall be an implementation-defined mapping between the delimited sequence and the external source file name. The implementation shall provide unique mappings for sequences consisting of one or more letters (as defined in 5.2.1) followed by a period (**`.`**) and a single letter. The implementation may ignore the distinctions of alphabetical case and restrict the mapping to six significant characters before the period.

[6] A **`#include`** preprocessing directive may appear in a source file that has been read because of a **`#include`** directive in another file, up to an implementation-defined nesting limit (see 5.2.4.1).

Examples

[7]

1. The most common uses of **`#include`** preprocessing directives are as in the following:

100. Note that adjacent string literals are not concatenated into a single string literal (see the translation phases in 5.1.1.2); thus, an expansion that results in two string literals is an invalid directive.

```
#include <stdio.h>
#include "myprog.h"
```

2. This illustrates macro-replaced `#include` directives:

```
#if VERSION == 1
     #define INCFILE  "vers1.h"
#elif VERSION == 2
     #define INCFILE  "vers2.h"   /* and so on */
#else
     #define INCFILE  "versN.h"
#endif
#include INCFILE
```

Forward references: macro replacement (6.8.3).

6.8.3 Macro replacement

Constraints

[1] Two replacement lists are identical if and only if the preprocessing tokens in both have the same number, ordering, spelling, and white-space separation, where all white-space separations are considered identical.

[2] An identifier currently defined as a macro without use of lparen (an *object-like* macro) shall not be redefined by another `#define` preprocessing directive unless the second definition is an object-like macro definition and the two replacement lists are identical.

[3] An identifier currently defined as a macro using lparen (a *function-like* macro) may be redefined by another `#define` preprocessing directive provided that the second definition is a function-like macro definition that has the same number and spelling of parameters, and the two replacement lists are identical.

[4] The number of arguments, including those arguments consisting of no preprocessing tokens, in an invocation of a function-like macro shall agree with the number of parameters in the macro definition, and there shall exist a `)` preprocessing token that terminates the invocation.

[5] A parameter identifier in a function-like macro shall be uniquely declared within its scope.

Semantics

[6] The identifier immediately following the `define` is called the *macro name*. There is one name space for macro names. Any white-space characters preceding or following the replacement list of preprocessing tokens are not considered part of the replacement list for either form of macro.

[7] If a `#` preprocessing token, followed by an identifier, occurs lexically at the point at which a preprocessing directive could begin, the identifier is not subject to macro replacement.

[8] A preprocessing directive of the form

`# define` *identifier replacement-list new-line*

defines an object-like macro that causes each subsequent instance of the macro name[101] to be replaced by the replacement list of preprocessing tokens that constitute the remainder of the directive. The replacement list is then rescanned for more macro names as specified below.

[9] A preprocessing directive of the form

`# define` *identifier lparen identifier-list*$_{opt}$ **`)`** *replacement-list new-line*

defines a function-like macro with arguments, similar syntactically to a function call. The parameters are specified by the optional list of identifiers, whose scope extends from their declaration in the identifier list until the new-line character that terminates the **`#define`** preprocessing directive. Each subsequent instance of the function-like macro name followed by a **`(`** as the next preprocessing token introduces the sequence of preprocessing tokens that is replaced by the replacement list in the definition (an invocation of the macro). The replaced sequence of preprocessing tokens is terminated by the matching **`)`** preprocessing token, skipping intervening matched pairs of left and right parenthesis preprocessing tokens. Within the sequence of preprocessing tokens making up an invocation of a function-like macro, new-line is considered a normal white-space character.

[10] The sequence of preprocessing tokens bounded by the outside-most matching parentheses forms the list of arguments for the function-like macro. The individual arguments within the list are separated by comma preprocessing tokens, but comma preprocessing tokens between matching inner parentheses do not separate arguments. If there are sequences of preprocessing tokens within the list of arguments that would otherwise act as preprocessing directives, the behavior is undefined.

6.8.3.1 Argument substitution

[1] After the arguments for the invocation of a function-like macro have been identified, argument substitution takes place. A parameter in the replacement list, unless preceded by a `#` or `##` preprocessing token or followed by a `##` preprocessing token (see below), is replaced by the corresponding argument after all macros contained therein have been expanded. Before being substituted, each argument's preprocessing tokens are completely macro replaced as if they formed the rest of the translation unit; no other preprocessing tokens are available.

---

101. Since, by macro-replacement time, all character constants and string literals are preprocessing tokens, not sequences possibly containing identifier-like subsequences (see 5.1.1.2, translation phases), they are never scanned for macro names or parameters.

6.8.3.2 The # operator

Constraints

[1] Each **#** preprocessing token in the replacement list for a function-like macro shall be followed by a parameter as the next preprocessing token in the replacement list.

Semantics

[2] If, in the replacement list, a parameter is immediately preceded by a **#** preprocessing token, both are replaced by a single character string literal preprocessing token that contains the spelling of the preprocessing token sequence for the corresponding argument. Each occurrence of white space between the argument's preprocessing tokens becomes a single space character in the character string literal. White space before the first preprocessing token and after the last preprocessing token comprising the argument is deleted. Otherwise, the original spelling of each preprocessing token in the argument is retained in the character string literal, except for special handling for producing the spelling of string literals and character constants: a **** character is inserted before each **"** and **** character of a character constant or string literal (including the delimiting **"** characters). If the replacement that results is not a valid character string literal, the behavior is undefined. The character string literal corresponding to an empty argument is **""**. The order of evaluation of **#** and **##** operators is unspecified.

6.8.3.3 The ## operator

Constraints

[1] A **##** preprocessing token shall not occur at the beginning or at the end of a replacement list for either form of macro definition.

Semantics

[2] If, in the replacement list, a parameter is immediately preceded or followed by a **##** preprocessing token, the parameter is replaced by the corresponding argument's preprocessing token sequence; however, if an argument consists of no preprocessing tokens, the parameter is replaced by a *placemarker* preprocessing token instead.

[3] For both object-like and function-like macro invocations, before the replacement list is reexamined for more macro names to replace, each instance of a **##** preprocessing token in the replacement list (not from an argument) is deleted and the preceding preprocessing token is concatenated with the following preprocessing token (placemarker preprocessing tokens are handled specially: concatentation of two placemarkers results in a single placemarker preprocessing token; concatentation of a placemarker with a non-placemarker preprocessing token results in the non-placemarker preprocessing token). If the result is not a valid preprocessing token, the behavior is undefined. The resulting token is available for further macro replacement. The order of evaluation of **##** operators is unspecified.

Example

[4]

```
#define hash_hash # ## #
#define mkstr(a) # a
#define in_between(a) mkstr(a)
#define join(c, d) in_between(c hash_hash d)

char p[] = join(x, y); /* equivalent to */
                       /* char p[] = "x ## y"; */
```

The expansion produces, at various stages:

```
join(x, y)

in_between(x hash_hash y)

in_between(x ## y)

mkstr(x ## y)

"x ## y"
```

In other words, expanding **##** produces a new token, consisting of two adjacent sharp signs, but this new token is not the catenation operator.

6.8.3.4 Rescanning and further replacement

[1] After all parameters in the replacement list have been substituted and **#** and **##** processing has taken place, all placemarker preprocessing tokens are removed, then the resulting preprocessing token sequence is rescanned with all subsequent preprocessing tokens of the source file for more macro names to replace.

[2] If the name of the macro being replaced is found during this scan of the replacement list (not including the rest of the source file's preprocessing tokens), it is not replaced. Further, if any nested replacements encounter the name of the macro being replaced, it is not replaced. These nonreplaced macro name preprocessing tokens are no longer available for further replacement even if they are later (re)examined in contexts in which that macro name preprocessing token would otherwise have been replaced.

[3] The resulting completely macro-replaced preprocessing token sequence is not processed as a preprocessing directive even if it resembles one.

6.8.3.5 Scope of macro definitions

[1] A macro definition lasts (independent of block structure) until a corresponding **`#undef`** directive is encountered or (if none is encountered) until the end of the translation unit.

[2] A preprocessing directive of the form

`# undef` *identifier new-line*

causes the specified identifier no longer to be defined as a macro name. It is ignored if the specified identifier is not currently defined as a macro name.

Examples

[3]

1. The simplest use of this facility is to define a ‘‘manifest constant,’’ as in

```
#define TABSIZE 100

int table[TABSIZE];
```

2. The following defines a function-like macro whose value is the maximum of its arguments. It has the advantages of working for any compatible types of the arguments and of generating in-line code without the overhead of function calling. It has the disadvantages of evaluating one or the other of its arguments a second time (including side effects) and generating more code than a function if invoked several times. It also cannot have its address taken, as it has none.

```
#define max(a, b) ((a) > (b) ? (a) : (b))
```

The parentheses ensure that the arguments and the resulting expression are bound properly.

3. To illustrate the rules for redefinition and reexamination, the sequence

```
#define x      3
#define f(a)   f(x * (a))
#undef  x
#define x      2
#define g      f
#define z      z[0]
#define h      g(~
#define m(a)   a(w)
#define w      0,1
#define t(a)   a
#define p()    int
#define q(x)   x
#define r(x,y) x ## y
#define str(x) # x

f(y+1) + f(f(z)) % t(t(g)(0) + t)(1);
g(x+(3,4)-w) | h 5) & m
     (f)^m(m);
p() i[q()] = { q(1), r(2,3), r(4,), r(,5), r(,) };  |
char c[2][6] = { str(hello), str() };               |
```

results in

```
f(2 * (y+1)) + f(2 * (f(2 * (z[0])))) % f(2 * (0)) + t(1);
f(2 * (2+(3,4)-0,1)) | f(2 * (~ 5)) & f(2 * (0,1))^m(0,1);
int i[] = { 1, 23, 4, 5,  };                               |
char c[2][6] = { "hello", "" };
```

4. To illustrate the rules for creating character string literals and concatenating tokens, the sequence

```
#define str(s)      # s
#define xstr(s)     str(s)
#define debug(s, t) printf("x" # s "= %d, x" # t "= %s", \
                    x ## s, x ## t)
#define INCFILE(n)  vers ## n  /* from previous #include example */
#define glue(a, b)  a ## b
#define xglue(a, b) glue(a, b)
#define HIGHLOW     "hello"
#define LOW         LOW ", world"

debug(1, 2);
fputs(str(strncmp("abc\0d", "abc", '\4')  /* this goes away */|
   == 0) str(: @\n), s);
#include xstr(INCFILE(2).h)
glue(HIGH, LOW);
xglue(HIGH, LOW)
```

results in

```
printf("x" "1" "= %d, x" "2" "= %s", x1, x2);
fputs("strncmp(\"abc\\0d\", \"abc\", '\\4') == 0" ": @\n", s);
#include "vers2.h"     (after macro replacement, before file access)
"hello";
"hello" ", world"
```

or, after concatenation of the character string literals,

```
printf("x1= %d, x2= %s", x1, x2);
fputs("strncmp(\"abc\\0d\", \"abc\", '\\4') == 0: @\n", s);
#include "vers2.h"     (after macro replacement, before file access)
"hello";
"hello, world"
```

Space around the **#** and **##** tokens in the macro definition is optional.

5. To illustrate the rules for

   placemarker **##** *placemarker*

   the sequence

```
#define t(x,y,z) x ## y ## z
int j[] = { t(1,2,3), t(,4,5), t(6,,7), t(8,9,),
            t(10,,), t(,11,), t(,,12), t(,,) };
```

   results in

```
int j[] = { 123, 45, 67, 89,
             10, 11, 12,  };
```

6. And finally, to demonstrate the redefinition rules, the following sequence is valid.

```
#define OBJ_LIKE      (1-1)
#define OBJ_LIKE      /* white space */ (1-1) /* other */
#define FTN_LIKE(a)   ( a )
#define FTN_LIKE( a )( /* note the white space */ \
                       a /* other stuff on this line
                         */ )
```

   But the following redefinitions are invalid:

```
#define OBJ_LIKE    (0)     /* different token sequence */
#define OBJ_LIKE    (1 - 1) /* different white space */
#define FTN_LIKE(b) ( a )   /* different parameter usage */
#define FTN_LIKE(b) ( b )   /* different parameter spelling */
```

6.8.4 Line control

Constraints

[1] The string literal of a **`#line`** directive, if present, shall be a character string literal.

Semantics

[2] The *line number* of the current source line is one greater than the number of new-line characters read or introduced in translation phase 1 (5.1.1.2) while processing the source file to the current token.

[3] A preprocessing directive of the form

> **`# line`** *digit-sequence new-line*

causes the implementation to behave as if the following sequence of source lines begins with a source line that has a line number as specified by the digit sequence (interpreted as a decimal integer). The digit sequence shall not specify zero, nor a number greater than 2147483647.

[4] A preprocessing directive of the form

> **`# line`** *digit-sequence* **`"`***s-char-sequence*$_{opt}$**`"`** *new-line*

sets the line number similarly and changes the presumed name of the source file to be the contents of the character string literal.

[5] A preprocessing directive of the form

> **`# line`** *pp-tokens new-line*

(that does not match one of the two previous forms) is permitted. The preprocessing tokens after **`line`** on the directive are processed just as in normal text (each identifier currently defined as a macro name is replaced by its replacement list of preprocessing tokens). The directive resulting after all replacements shall match one of the two previous forms and is then processed as appropriate.

6.8.5 Error directive

Semantics

[1] A preprocessing directive of the form

> **`# error`** *pp-tokens*$_{opt}$ *new-line*

causes the implementation to produce a diagnostic message that includes the specified sequence of preprocessing tokens.

6.8.6 Pragma directive

Semantics

[1] A preprocessing directive of the form

> **`# pragma`** *pp-tokens*$_{opt}$ *new-line*

causes the implementation to behave in an implementation-defined manner. Any pragma that is not recognized by the implementation is ignored.

6.8.7 Null directive

Semantics

[1] A preprocessing directive of the form

> **`#`** *new-line*

has no effect.

6.8.8 Predefined macro names

[1] The following macro names shall be defined by the implementation:

`__LINE__` The line number of the current source line (a decimal constant).

`__FILE__` The presumed name of the source file (a character string literal).

`__DATE__` The date of translation of the source file (a character string literal of the form **`"Mmm dd yyyy"`**, where the names of the months are the same as those generated by the **`asctime`** function, and the first character of **`dd`** is a space character if the value is less than 10). If the date of translation is not available, an implementation-defined valid date shall be supplied.

`__TIME__` The time of translation of the source file (a character string literal of the form **`"hh:mm:ss"`** as in the time generated by the **`asctime`** function). If the time of translation is not available, an implementation-defined valid time shall be supplied.

`__STDC__` The decimal constant 1, intended to indicate a conforming implementation.

`__STDC_VERSION__` The decimal constant **`199409L`**, intended to indicate an implementation conforming to Amendment 1. |

[2] The values of the predefined macros (except for **`__LINE__`** and **`__FILE__`**) remain constant throughout the translation unit.

[3] None of these macro names, nor the identifier **`defined`**, shall be the subject of a **`#define`** or a **`#undef`** preprocessing directive. All predefined macro names shall begin with a leading underscore followed by an uppercase letter or a second underscore.

Forward references: the **`asctime`** function (7.14.3.1).

6.8.9 Pragma operator

Semantics

[1] In translation phase 4, each unary operator expression of the form:

`pragma (` *string-literal* **`)`**

is executed as follows. The *string-literal* is ‘‘de-stringized’’ by deleting the **`L`** prefix, if present, deleting the leading and trailing double-quotes, replacing each escape sequence **`\"`** by a double-quote, and relacing each escape sequence **`\`** by a single backslash. The resulting sequence of characters is processed through translation phase 3 to produce pre-processing tokens that are executed as if they were the *pp-tokens* in a pragma directive. The original four preprocessing tokens in the user operator expression are replaced by the (possibly empty) implementation-defined sequence of preprocessing tokens that result from that execution.

6.9 Future language directions

6.9.1 External names

[1] Restriction of the significance of an external name to fewer than 31 characters or to only one case is an obsolescent feature that is a concession to existing implementations.

6.9.2 Character escape sequences

[1] Lowercase letters as escape sequences are reserved for future standardization. Other characters may be used in extensions.

6.9.3 Storage-class specifiers

[1] The placement of a storage-class specifier other than at the beginning of the declaration specifiers in a declaration is an obsolescent feature.

6.9.4 Function declarators

[1] The use of function declarators with empty parentheses (not prototype-format parameter type declarators) is an obsolescent feature.

6.9.5 Function definitions

[1] The use of function definitions with separate parameter identifier and declaration lists (not prototype-format parameter type and identifier declarators) is an obsolescent feature.

6.9.6 Array parameters

[1] The use of two parameters declared with an array type (prior to their adjustment to pointer type) in separate lvalues to designate the same object is an obsolescent feature.

7. Library

7.1 Introduction

7.1.1 Definitions of terms

[1] A *string* is a contiguous sequence of characters terminated by and including the first null character. A ‘‘pointer to’’ a string is a pointer to its initial (lowest addressed) character. The ‘‘length’’ of a string is the number of characters preceding the null character and its ‘‘value’’ is the sequence of the values of the contained characters, in order.

[2] A *letter* is a printing character in the execution character set corresponding to any of the 52 required lowercase and uppercase letters in the source character set, listed in 5.2.1.

[3] The *decimal-point character* is the character used by functions that convert floating-point numbers to or from character sequences to denote the beginning of the fractional part of such character sequences.[102] It is represented in the text and examples by a period, but may be changed by the **`setlocale`** function.

[4] A *wide character* is a code value (a binary encoded integer) of an object of type **`wchar_t`** that corresponds to a member of the extended character set.[103]

[5] A *null wide character* is a wide character with code value zero.

[6] A *wide string* is a contiguous sequence of wide characters terminated by and including the first null wide character. A *pointer to a wide string* is a pointer to its initial (lowest addressed) wide character. The *length of a wide string* is the number of wide characters preceding the null wide character and the *value of a wide string* is the sequence of code values of the contained wide characters, in order.

[7] A *shift sequence* is a contiguous sequence of bytes within a multibyte string that (potentially) causes a change in shift state. (See subclause 5.2.1.2.) A shift sequence shall not have a corresponding wide character; it is instead taken to be an adjunct to an adjacent multibyte character.[104]

---

102. The functions that make use of the decimal-point character are **`localeconv`**, **`fprintf`**, **`fscanf`**, **`printf`**, **`scanf`**, **`sprintf`**, **`sscanf`**, **`vfprintf`**, **`vprintf`**, **`vsprintf`**, **`atof`**, and **`strtod`**.

103. An equivalent definition can be found in subclause 6.1.3.4.

104. For state-dependent encodings, the values for **`MB_CUR_MAX`** and **`MB_LEN_MAX`** must thus be large enough to count all the bytes in any complete multibyte character plus at least one adjacent shift sequence of maximum length. Whether these counts provide for more than one shift sequence is the implementation’s choice.

Forward references: character handling (7.3), the **setlocale** function (7.5.1.1).

7.1.2 Standard headers

[1] Each library function is declared in a *header*,[105] whose contents are made available by the **#include** preprocessing directive. The header declares a set of related functions, plus any necessary types and additional macros needed to facilitate their use.

[2] The standard headers are

<assert.h>	**<ctype.h>**	**<errno.h>**
<float.h>	**<inttypes.h>**	**<iso646.h>**
<limits.h>	**<locale.h>**	**<math.h>**
<setjmp.h>	**<signal.h>**	**<stdarg.h>**
<stddef.h>	**<stdio.h>**	**<stdlib.h>**
<string.h>	**<time.h>**	**<wchar.h>**
<wctype.h>		

[3] If a file with the same name as one of the above **<** and **>** delimited sequences, not provided as part of the implementation, is placed in any of the standard places for a source file to be included, the behavior is undefined.

[4] Headers may be included in any order; each may be included more than once in a given scope, with no effect different from being included only once, except that the effect of including **<assert.h>** depends on the definition of **NDEBUG**. If used, a header shall be included outside of any external declaration or definition, and it shall first be included before the first reference to any of the functions or objects it declares, or to any of the types or macros it defines. However, if an identifier is declared or defined in more than one header, the second and subsequent associated headers may be included after the initial reference to the identifier. The program shall not have any macros with names lexically identical to keywords currently defined prior to the inclusion. *

[5] Any definition of an object-like macro described in this clause shall expand to code that is fully protected by parentheses where necessary, so that it groups in an arbitrary expression as if it were a single identifier. *

Forward references: diagnostics (7.2).

105. A header is not necessarily a source file, nor are the **<** and **>** delimited sequences in header names necessarily valid source file names.

7.1.3 Reserved identifiers

[1] Each header declares or defines all identifiers listed in its associated subclause, and optionally declares or defines identifiers listed in its associated future library directions subclause and identifiers which are always reserved either for any use or for use as file scope identifiers.

— All identifiers that begin with an underscore and either an uppercase letter or another underscore are always reserved for any use.

— All identifiers that begin with an underscore are always reserved for use as identifiers with file scope in both the ordinary identifier and tag name spaces.

— Each macro name listed in any of the following subclauses (including the future library directions) is reserved for any use if any of its associated headers is included.

— All identifiers with external linkage in any of the following subclauses (including the future library directions) are always reserved for use as identifiers with external linkage.[106]

— Each identifier with file scope listed in any of the following subclauses (including the future library directions) is reserved for use as an identifier with file scope in the same name space if any of its associated headers is included.

[2] No other identifiers are reserved. If the program declares or defines an identifier with the same name as an identifier reserved in that context (other than as allowed by 7.1.7), the behavior is undefined.[107]

7.1.4 Errors `<errno.h>`

[1] The header **`<errno.h>`** defines several macros, all relating to the reporting of error conditions.

[2] The macros are

```
EDOM
EILSEQ
ERANGE
```

which expand to integral constant expressions with distinct nonzero values, suitable for use in **`#if`** preprocessing directives; and

```
errno
```

---

106. The list of reserved identifiers with external linkage includes **`errno`**, **`setjmp`**, and **`va_end`**.

107. Since macro names are replaced whenever found, independent of scope and name space, macro names matching any of the reserved identifier names must not be defined if an associated header, if any, is included.

which expands to a modifiable lvalue[108] that has type **int**, the value of which is set to a positive error number by several library functions. It is unspecified whether **errno** is a macro or an identifier declared with external linkage. If a macro definition is suppressed in order to access an actual object, or a program defines an identifier with the name **errno**, the behavior is undefined.

[3] The value of **errno** is zero at program startup, but is never set to zero by any library function.[109] The value of **errno** may be set to nonzero by a library function call whether or not there is an error, provided the use of **errno** is not documented in the description of the function in this International Standard.

[4] Additional macro definitions, beginning with **E** and a digit or **E** and an uppercase letter,[110] may also be specified by the implementation.

7.1.5 Limits **<float.h>** and **<limits.h>**

[1] The headers **<float.h>** and **<limits.h>** define several macros that expand to various limits and parameters.

[2] The macros, their meanings, and the constraints (or restrictions) on their values are listed in 5.2.4.2.

7.1.6 Common definitions **<stddef.h>**

[1] The following types and macros are defined in the standard header **<stddef.h>**. Some are also defined in other headers, as noted in their respective subclauses.

[2] The types are

ptrdiff_t

which is the signed integral type of the result of subtracting two pointers;

size_t

which is the unsigned integral type of the result of the **sizeof** operator; and

wchar_t

which is an integral type whose range of values can represent distinct codes for all members of the largest extended character set specified among the supported locales; the null character shall have the code value zero and each member of the basic

---

108. The macro **errno** need not be the identifier of an object. It might expand to a modifiable lvalue resulting from a function call (for example, ***errno()**).

109. Thus, a program that uses **errno** for error checking should set it to zero before a library function call, then inspect it before a subsequent library function call. Of course, a library function can save the value of **errno** on entry and then set it to zero, as long as the original value is restored if **errno**'s value is still zero just before the return.

110. See ‘‘future library directions’’ (7.18.1).

character set defined in 5.2.1 shall have a code value equal to its value when used as the lone character in an integer character constant.

[3] The macros are

`NULL`

which expands to an implementation-defined null pointer constant; and

`offsetof(`*type***`,`** *member-designator***`)`**

which expands to an integral constant expression that has type **`size_t`**, the value of which is the offset in bytes, to the structure member (designated by *member-designator*), from the beginning of its structure (designated by *type*). The *member-designator* shall be such that given

`static` *type* **`t;`**

then the expression **`&(t.`***member-designator***`)`** evaluates to an address constant. (If the specified member is a bit-field, the behavior is undefined.)

Forward references: localization (7.5).

7.1.7 Use of library functions

[1] Each of the following statements applies unless explicitly stated otherwise in the detailed descriptions that follow. If an argument to a function has an invalid value (such as a value outside the domain of the function, or a pointer outside the address space of the program, or a null pointer) or a type (after promotion) not expected by a function with variable number of arguments, the behavior is undefined. If a function argument is described as being an array, the pointer actually passed to the function shall have a value such that all address computations and accesses to objects (that would be valid if the pointer did point to the first element of such an array) are in fact valid. Any function declared in a header may be additionally implemented as a macro defined in the header, so a library function should not be declared explicitly if its header is included. Any macro definition of a function can be suppressed locally by enclosing the name of the function in parentheses, because the name is then not followed by the left parenthesis that indicates expansion of a macro function name. For the same syntactic reason, it is permitted to take the address of a library function even if it is also defined as a macro.[111] The use of **`#undef`** to remove any macro definition will also ensure that an actual function is referred to. Any invocation of a library function that is implemented as a macro shall expand to code that evaluates each of its arguments exactly once, fully protected by parentheses where necessary, so it is generally safe to use arbitrary expressions as arguments. Likewise, those

111. This means that an implementation must provide an actual function for each library function, even if it also provides a macro for that function.

function-like macros described in the following subclauses may be invoked in an expression anywhere a function with a compatible return type could be called.[112] All object-like macros listed as expanding to integral constant expressions shall additionally be suitable for use in **#if** preprocessing directives.

[2] Provided that a library function can be declared without reference to any type defined in a header, it is also permissible to declare the function, either explicitly or implicitly, and use it without including its associated header. If a function that accepts a variable number of arguments is not declared (explicitly or by including its associated header), the behavior is undefined.

Example

[3] The function **atoi** may be used in any of several ways:

— by use of its associated header (possibly generating a macro expansion)

```
#include <stdlib.h>
const char *str;
/*...*/
i = atoi(str);
```

— by use of its associated header (assuredly generating a true function reference)

112. Because external identifiers and some macro names beginning with an underscore are reserved, implementations may provide special semantics for such names. For example, the identifier **_BUILTIN_abs** could be used to indicate generation of in-line code for the **abs** function. Thus, the appropriate header could specify

```
#define abs(x) _BUILTIN_abs(x)
```

for a compiler whose code generator will accept it.

In this manner, a user desiring to guarantee that a given library function such as **abs** will be a genuine function may write

```
#undef abs
```

whether the implementation's header provides a macro implementation of **abs** or a built-in implementation. The prototype for the function, which precedes and is hidden by any macro definition, is thereby revealed also.

```
#include <stdlib.h>
#undef atoi
const char *str;
/*...*/
i = atoi(str);
```

or

```
#include <stdlib.h>
const char *str;
/*...*/
i = (atoi)(str);
```

— by explicit declaration

```
extern int atoi(const char *);
const char *str;
/*...*/
i = atoi(str);
```

— by implicit declaration

```
const char *str;
/*...*/
i = atoi(str);
```

7.2 Diagnostics `<assert.h>`

[1] The header **`<assert.h>`** defines the **`assert`** macro and refers to another macro,

```
NDEBUG
```

which is *not* defined by **`<assert.h>`**. If **`NDEBUG`** is defined as a macro name at the point in the source file where **`<assert.h>`** is included, the **`assert`** macro is defined simply as

```
#define assert(ignore) ((void)0)
```

[2] The **`assert`** macro shall be implemented as a macro, not as an actual function. If the macro definition is suppressed in order to access an actual function, the behavior is undefined.

7.2.1 Program diagnostics

7.2.1.1 The `assert` macro

Synopsis

[1]

```
#include <assert.h>
void assert(int expression);
```

Description

[2] The **`assert`** macro puts diagnostics into programs. When it is executed, if **`expression`** is false (that is, compares equal to 0), the **`assert`** macro writes information about the particular call that failed (including the text of the argument, the name of the source file, and the source line number — the latter are respectively the values of the preprocessing macros **`__FILE__`** and **`__LINE__`**) on the standard error file in an implementation-defined format.[113] It then calls the **`abort`** function.

Returns

[3] The **`assert`** macro returns no value.

Forward references: the **`abort`** function (7.12.4.1).

---

113. The message written might be of the form

Assertion failed: *expression*, file *xyz*, line *nnn*

7.3 Character handling `<ctype.h>`

[1] The header **`<ctype.h>`** declares several functions useful for testing and mapping characters.[114] In all cases the argument is an **`int`**, the value of which shall be representable as an **`unsigned char`** or shall equal the value of the macro **`EOF`**. If the argument has any other value, the behavior is undefined.

[2] The behavior of these functions is affected by the current locale. Those functions that have locale-specific aspects only when not in the **`"C"`** locale are noted below.

[3] The term *printing character* refers to a member of a locale-specific set of characters, each of which occupies one printing position on a display device; the term *control character* refers to a member of a locale-specific set of characters that are not printing characters.[115]

Forward references: **`EOF`** (7.11.1), localization (7.6).

7.3.1 Character testing functions

[1] The functions in this subclause return nonzero (true) if and only if the value of the argument **`c`** conforms to that in the description of the function.

7.3.1.1 The `isalnum` function

Synopsis

[1]

```
#include <ctype.h>
int isalnum(int c);
```

Description

[2] The **`isalnum`** function tests for any character for which **`isalpha`** or **`isdigit`** is true.

7.3.1.2 The `isalpha` function

Synopsis

[1]

```
#include <ctype.h>
int isalpha(int c);
```

Description

114. See ‘‘future library directions’’ (7.18.2).

115. In an implementation that uses the seven-bit ASCII character set, the printing characters are those whose values lie from 0x20 (space) through 0x7E (tilde); the control characters are those whose values lie from 0 (NUL) through 0x1F (US), and the character 0x7F (DEL).

[2] The **isalpha** function tests for any character for which **isupper** or **islower** is true, or any character that is one of a locale-specific set of characters for which none of **iscntrl**, **isdigit**, **ispunct**, or **isspace** is true. In the **"C"** locale, **isalpha** returns true only for the characters for which **isupper** or **islower** is true.

7.3.1.3 The iscntrl function

Synopsis

[1]

```
#include <ctype.h>
int iscntrl(int c);
```

Description

[2] The **iscntrl** function tests for any control character.

7.3.1.4 The isdigit function

Synopsis

[1]

```
#include <ctype.h>
int isdigit(int c);
```

Description

[2] The **isdigit** function tests for any decimal-digit character (as defined in 5.2.1).

7.3.1.5 The isgraph function

Synopsis

[1]

```
#include <ctype.h>
int isgraph(int c);
```

Description

[2] The **isgraph** function tests for any printing character except space (**' '**).

7.3.1.6 The islower function

Synopsis

[1]

```
#include <ctype.h>
int islower(int c);
```

Description

[2] The **islower** function tests for any character that is a lowercase letter or is one of a locale-specific set of characters for which none of **iscntrl**, **isdigit**, **ispunct**, or **isspace** is true. In the **"C"** locale, **islower** returns true only for the characters defined as lowercase letters (as defined in 5.2.1).

7.3.1.7 The isprint function

Synopsis

[1]

```
#include <ctype.h>
int isprint(int c);
```

Description

[2] The **isprint** function tests for any printing character including space (**' '**).

7.3.1.8 The ispunct function

Synopsis

[1]

```
#include <ctype.h>
int ispunct(int c);
```

Description

[2] The **ispunct** function tests for any printing character that is neither space (**' '**) nor a character for which **isalnum** is true.

7.3.1.9 The isspace function

Synopsis

[1]

```
#include <ctype.h>
int isspace(int c);
```

Description

[2] The **isspace** function tests for any character that is a standard white-space character or is one of a locale-specific set of characters for which **isalnum** is false. The standard white-space characters are the following: space (**' '**), form feed (**'\f'**), new-line (**'\n'**), carriage return (**'\r'**), horizontal tab (**'\t'**), and vertical tab (**'\v'**). In the **"C"** locale, **isspace** returns true only for the standard white-space characters.

7.3.1.10 The `isupper` function

Synopsis

[1]

```
#include <ctype.h>
int isupper(int c);
```

Description

[2] The **`isupper`** function tests for any character that is an uppercase letter or is one of a locale-specific set of characters for which none of **`iscntrl`**, **`isdigit`**, **`ispunct`**, or **`isspace`** is true. In the **`"C"`** locale, **`isupper`** returns true only for the characters defined as uppercase letters (as defined in 5.2.1).

7.3.1.11 The `isxdigit` function

Synopsis

[1]

```
#include <ctype.h>
int isxdigit(int c);
```

Description

[2] The **`isxdigit`** function tests for any hexadecimal-digit character (as defined in 6.1.3.2).

7.3.2 Character case mapping functions

7.3.2.1 The `tolower` function

Synopsis

[1]

```
#include <ctype.h>
int tolower(int c);
```

Description

[2] The **`tolower`** function converts an uppercase letter to the corresponding lowercase letter.

Returns

[3] If the argument is a character for which **`isupper`** is true and there is a corresponding character for which **`islower`** is true, the **`tolower`** function returns the corresponding character; otherwise, the argument is returned unchanged.

7.3.2.2 The `toupper` function

Synopsis

[1]

```
#include <ctype.h>
int toupper(int c);
```

Description

[2] The **`toupper`** function converts a lowercase letter to the corresponding uppercase letter.

Returns

[3] If the argument is a character for which **`islower`** is true and there is a corresponding character for which **`isupper`** is true, the **`toupper`** function returns the corresponding character; otherwise, the argument is returned unchanged.

7.4 Integral types `<inttypes.h>`

7.4.1 Introduction

[1] This header defines, via typedef, a set of integral types that have the specified precisions. It defines integers, signed and unsigned, of the following categories:

— integers of a certain fixed size;

— integers that are at least the specified sizes;

— integers that are large enough to hold a pointer;

— largest integral type supported in the implementation;

— the most efficient integral types in the implementation;

— the most efficient integral types of a certain size.

[2] This header also defines macros for the limits of the integral types defined within this header, and macros defining conversion specifics suitable for use with the formatted input/output functions.

[3] A conforming implementation may support an execution environment in which one or more of the types described above cannot be implemented. For each such type, the implementation shall not provide the typedef from subclauses 7.4.2 through 7.4.7 that describes the type, nor shall it define the associated macros from 7.4.8 through 7.4.11.

7.4.2 Exact-sized, signed and unsigned, integral types

[1] The following typedefs define integral types of fixed size. The typedefs have the general format of **int***N***_t** or **uint***N***_t** where *N* is the size, in bits of that type. For example, **int8_t** is a signed integer type whose size is exactly 8 bits.

[2] The following are the signed fixed-size integral types:

```
int8_t
int16_t
int32_t
int64_t
```

[3] The following are the unsigned fixed-size integral types:

```
uint8_t
uint16_t
uint32_t
uint64_t
```

7.4.3 Largest integral types

[1] The largest signed integral type is:

`intmax_t`

[2] The largest unsigned integral type is:

`uintmax_t`

7.4.4 Integer types for `void *` pointers

[1] A signed integral type large enough to hold a **`(void *)`**: |

`intptr_t`

[2] An unsigned integral type large enough to hold a **`(void *)`**: |

`uintptr_t`

7.4.5 Most efficient types

[1] The most efficient signed integral type of the implementation is: *

`intfast_t`

[2] The most efficient unsigned integral type of the implementation is: *

`uintfast_t`

7.4.6 Small types of a specified size

[1] The following typedefs define integral types that have a minimum size. The typedefs have the general format of **`int_least`***N***`_t`** or **`uint_least`***N***`_t`** where *N* is the minimum size, in bits, of the type. For example: **`int_least32_t`** is a signed integral type whose size is at least 32 bits. |

[2] The signed integral types with a minimum size of *N* bits are:

```
int_least8_t
int_least16_t
int_least32_t
int_least64_t
```

[3] The unsigned integral types with a minimum size of *N* bits are:

```
uint_least8_t
uint_least16_t
uint_least32_t
uint_least64_t
```

7.4.7 Most efficient types of a specified size

[1] The following typedefs define the most efficient integral types having the specified minimum precision. The typedef name has the general format of **int_fast***N***_t** or **uint_fast***N***_t** where *N* is the minimum size, in bits, of the type. For example: **int_fast16_t** is the most efficient signed integral type in the implementation whose size is at least 16 bits.

[2] The most efficient signed integral types with a minimum size of *N* bits are:

```
int_fast8_t
int_fast16_t
int_fast32_t
int_fast64_t
```

[3] The most efficient unsigned integral types with a minimum size of *N* bits are:

```
uint_fast8_t
uint_fast16_t
uint_fast32_t
uint_fast64_t
```

7.4.8 Limits of integral types

[1] The following macros define the implementation-defined limits, minimum and maximum, of signed and unsigned fixed size integral types. The typedef name has a one-to-one correspondence with the fixed-size integral types defined in subclause 7.4.2. Only types that are supported by the implementation shall have their limits defined here.[116] The minimums of signed integral types are:

```
#define INT8_MIN  (-128)
#define INT16_MIN (-32767-1)
#define INT32_MIN (-2147483647-1)
#define INT64_MIN (-9223372036854775807-1)
```

The maximums of signed integral types are:

```
#define INT8_MAX  (127)
#define INT16_MAX (32767)
#define INT32_MAX (2147483647)
#define INT64_MAX (9223372036854775807)
```

The maximums of unsigned integral types are:

116. Programs can test if the implementation supports a specified integral type by testing for the existence of the macro defining the maximum value of that type. For example, **#ifdef UINT64_MAX** will test test true if unsigned 64-bit integers are supported by the implementation.

```
#define UINT8_MAX  (255U)
#define UINT16_MAX (65536U)
#define UINT32_MAX (4294967295U)
#define UINT64_MAX (18446744073709551615U)
```

[2] The following macros define implementation-defined limits for signed and unsigned integral types with a specified minimum size. There is a one-to-one correspondence between these macros and the typedefs described in subclause 7.4.6.

[3] The minimums of signed integral types having a specified minimum size are:

```
#define INT_LEAST8_MIN
#define INT_LEAST16_MIN
#define INT_LEAST32_MIN
#define INT_LEAST64_MIN
```

[4] The maximums of signed integral types having a specified minimum size are:

```
#define INT_LEAST8_MAX
#define INT_LEAST16_MAX
#define INT_LEAST32_MAX
#define INT_LEAST64_MAX
```

[5] The maximums of unsigned integral types having a specified minimum size are:

```
#define UINT_LEAST8_MAX
#define UINT_LEAST16_MAX
#define UINT_LEAST32_MAX
#define UINT_LEAST64_MAX
```

[6] The following macros define implementation-defined limits for the most efficient signed and unsigned integral types with a specified minimum size. There is a one-to-one correspondence between these macros and the typedefs described in subclause 7.4.7.

7.4.9 Limits of most efficient intregral types

[1] The minimums of signed integral types having a specified minimum size are:

```
#define INT_FAST8_MIN
#define INT_FAST16_MIN
#define INT_FAST32_MIN
#define INT_FAST64_MIN
```

[2] The maximums of signed integral types having a specified minimum size are:

```
#define INT_FAST8_MAX
#define INT_FAST16_MAX
#define INT_FAST32_MAX
#define INT_FAST64_MAX
```

[3] The maximums of unsigned integral types having a specified minimum size are:

```
#define UINT_FAST8_MAX
#define UINT_FAST16_MAX
#define UINT_FAST32_MAX
#define UINT_FAST64_MAX
```

[4] The minimum of the most efficient signed integral type is:

```
#define INTFAST_MIN
```

[5] The maximum of the most efficient signed integral type is:

```
#define INTFAST_MAX
```

[6] The maximum of the most efficient unsigned integral type is:

```
#define UINTFAST_MAX
```

[7] The following macros define implementation-defined limits for the largest integral types, signed and unsigned, in the implementation. They correspond to the types defined in subclause 7.4.3.

[8] The minimum for the largest signed integral type is:

```
#define INTMAX_MIN
```

[9] The maximum for the largest signed integral type is:

```
#define INTMAX_MAX
```

The maximum for the largest unsigned integral type is:

```
#define UINTMAX_MAX
```

[10] The following macros are used for testing whether the types **`intptr_t`** and **`uintptr_t`** are defined in this header.

```
#define INTPTR_MAX
#define UINTPTR_MAX
```

7.4.10 Macros for creating constants

[1] The following macros create constants of the types defined in this subclause. These macros have the general format of of **INT***N***_C** or **UINT***N***_C** where *N* is the size, in bits, of the constant to be defined.

```
#define __CONCAT__(A,B) A ## B

#define INT8_C(c)
#define INT16_C(c)
#define INT32_C(c)
#define INT64_C(c)

#define UINT8_C(c)
#define UINT16_C(c)
#define UINT32_C(c)
#define UINT64_C(c)

#define INTMAX_C(c)
#define UINTMAX_C(c)
```

7.4.11 Macros for format specifiers

[1] The following macros can be used with the corresponding integral types within the format parameter of the formatted input/output functions. The format of the names of the macros are **PRI** (for the **printf** family) or **SCN** (for the **scanf** family), followed by the conversion specifier, and then followed by the datatype size. For example, **PRId32** is used as a format string to print an integer of type **int32_t**.[117]

[2] The **printf** macros for signed integers are:

```
#define PRId8
#define PRId16
#define PRId32
#define PRId64

#define PRIdLEAST8
#define PRIdLEAST16
#define PRIdLEAST32
#define PRIdLEAST64

#define PRIdFAST8
#define PRIdFAST16
#define PRIdFAST32
#define PRIdFAST64
```

117. Separate macros are given for **printf** and **scanf** functions because, typically, different format specifiers are required for **printf** and **scanf** even when the type is the same.

```
#define PRIi8
#define PRIi16
#define PRIi32
#define PRIi64

#define PRIiLEAST8
#define PRIiLEAST16
#define PRIiLEAST32
#define PRIiLEAST64

#define PRIiFAST8
#define PRIiFAST16
#define PRIiFAST32
#define PRIiFAST64

#define PRIo8
#define PRIo16
#define PRIo32
#define PRIo64

#define PRIoLEAST8
#define PRIoLEAST16
#define PRIoLEAST32
#define PRIoLEAST64

#define PRIoFAST8
#define PRIoFAST16
#define PRIoFAST32
#define PRIoFAST64

#define PRIx8
#define PRIx16
#define PRIx32
#define PRIx64

#define PRIxLEAST8
#define PRIxLEAST16
#define PRIxLEAST32
#define PRIxLEAST64

#define PRIxFAST8
#define PRIxFAST16
#define PRIxFAST32
#define PRIxFAST64
```

```
#define PRIX8
#define PRIX16
#define PRIX32
#define PRIX64

#define PRIXLEAST8
#define PRIXLEAST16
#define PRIXLEAST32
#define PRIXLEAST64

#define PRIXFAST8
#define PRIXFAST16
#define PRIXFAST32
#define PRIXFAST64
```

[3] The **printf** macros for unsigned integers are:

```
#define PRIu8
#define PRIu16
#define PRIu32
#define PRIu64

#define PRIuLEAST8
#define PRIuLEAST16
#define PRIuLEAST32
#define PRIuLEAST64

#define PRIuFAST8
#define PRIuFAST16
#define PRIuFAST32
#define PRIuFAST64
```

[4] The **scanf** macros for unsigned integers are:

```
#define SCNd16
#define SCNd32
#define SCNd64

#define SCNi16
#define SCNi32
#define SCNi64

#define SCNo16
#define SCNo32
#define SCNo64

#define SCNu16
#define SCNu32
#define SCNu64

#define SCNx16
#define SCNx32
#define SCNx64
```

[5] The **printf** and **scanf** macros for **intmax_t** and **uintmax_t** are:

```
#define PRIdMAX
#define PRIoMAX
#define PRIxMAX
#define PRIuMAX

#define SCNiMAX
#define SCNdMAX
#define SCNoMAX
#define SCNxMAX
```

[6] The **printf** and **scanf** macros for **intfast_t** and **uintfast_t** are:

```
#define PRIdFAST
#define PRIoFAST
#define PRIxFAST
#define PRIuFAST

#define SCNiFAST
#define SCNdFAST
#define SCNoFAST
#define SCNxFAST
```

[7] The **printf** and **scanf** macros for **intptr_t** and **uintptr_t** are:

```
#define PRIdPTR
#define PRIoPTR
#define PRIxPTR
#define PRIXPTR
#define PRIuPTR

#define SCNiPTR
#define SCNdPTR
#define SCNoPTR
#define SCNxPTR
```

7.5 Localization `<locale.h>`

[1] The header `<locale.h>` declares two functions, one type, and defines several macros.

[2] The type is

```
struct lconv
```

which contains members related to the formatting of numeric values. The structure shall contain at least the following members, in any order. The semantics of the members and their normal ranges is explained in 7.5.2.1. In the `"C"` locale, the members shall have the values specified in the comments.

```
char *decimal_point;       /* "." */
char *thousands_sep;       /* "" */
char *grouping;            /* "" */
char *int_curr_symbol;     /* "" */
char *currency_symbol;     /* "" */
char *mon_decimal_point;   /* "" */
char *mon_thousands_sep;   /* "" */
char *mon_grouping;        /* "" */
char *positive_sign;       /* "" */
char *negative_sign;       /* "" */
char int_frac_digits;      /* CHAR_MAX */
char frac_digits;          /* CHAR_MAX */
char p_cs_precedes;        /* CHAR_MAX */
char p_sep_by_space;       /* CHAR_MAX */
char n_cs_precedes;        /* CHAR_MAX */
char n_sep_by_space;       /* CHAR_MAX */
char p_sign_posn;          /* CHAR_MAX */
char n_sign_posn;          /* CHAR_MAX */
```

[3] The macros defined are `NULL` (described in 7.1.6); and

```
LC_ALL
LC_COLLATE
LC_CTYPE
LC_MONETARY
LC_NUMERIC
LC_TIME
```

which expand to integral constant expressions with distinct values, suitable for use as the first argument to the `setlocale` function. Additional macro definitions, beginning with the characters `LC_` and an uppercase letter,[118] may also be specified by the implementation.

7.5.1 Locale control

7.5.1.1 The `setlocale` function

Synopsis

[1]

```
#include <locale.h>
char *setlocale(int category, const char *locale);
```

Description

[2] The **setlocale** function selects the appropriate portion of the program's locale as specified by the **category** and **locale** arguments. The **setlocale** function may be used to change or query the program's entire current locale or portions thereof. The value **LC_ALL** for **category** names the program's entire locale; the other values for **category** name only a portion of the program's locale. **LC_COLLATE** affects the behavior of the **strcoll** and **strxfrm** functions. **LC_CTYPE** affects the behavior of the character handling functions[119] and the multibyte functions. **LC_MONETARY** affects the monetary formatting information returned by the **localeconv** function. **LC_NUMERIC** affects the decimal-point character for the formatted input/output functions and the string conversion functions, as well as the nonmonetary formatting information returned by the **localeconv** function. **LC_TIME** affects the behavior of the **strftime** function.

[3] A value of **"C"** for **locale** specifies the minimal environment for C translation; a value of **""** for **locale** specifies the locale-specific native environment. Other implementation-defined strings may be passed as the second argument to **setlocale**.

[4] At program startup, the equivalent of

```
setlocale(LC_ALL, "C");
```

is executed.

[5] The implementation shall behave as if no library function calls the **setlocale** function.

Returns

[6] If a pointer to a string is given for **locale** and the selection can be honored, the **setlocale** function returns a pointer to the string associated with the specified **category** for the new locale. If the selection cannot be honored, the **setlocale**

---

118. See ‘‘future library directions’’ (7.18.3).

119. The only functions in 7.3 whose behavior is not affected by the current locale are **isdigit** and **isxdigit**.

function returns a null pointer and the program's locale is not changed.

[7] A null pointer for `locale` causes the `setlocale` function to return a pointer to the string associated with the `category` for the program's current locale; the program's locale is not changed.[120]

[8] The pointer to string returned by the `setlocale` function is such that a subsequent call with that string value and its associated category will restore that part of the program's locale. The string pointed to shall not be modified by the program, but may be overwritten by a subsequent call to the `setlocale` function.

Forward references: formatted input/output functions (7.11.6), the multibyte character functions (7.12.7), the multibyte string functions (7.12.8), string conversion functions (7.12.1), the `strcoll` function (7.13.4.3), the `strftime` function (7.14.3.5), the `strxfrm` function (7.13.4.5).

7.5.2 Numeric formatting convention inquiry

7.5.2.1 The `localeconv` function

Synopsis

[1]

```
#include <locale.h>
struct lconv *localeconv(void);
```

Description

[2] The `localeconv` function sets the components of an object with type `struct lconv` with values appropriate for the formatting of numeric quantities (monetary and otherwise) according to the rules of the current locale.

[3] The members of the structure with type `char *` are pointers to strings, any of which (except `decimal_point`) can point to `""`, to indicate that the value is not available in the current locale or is of zero length. The members with type `char` are nonnegative numbers, any of which can be `CHAR_MAX` to indicate that the value is not available in the current locale. The members include the following:

`char *decimal_point`
: The decimal-point character used to format nonmonetary quantities.

`char *thousands_sep`
: The character used to separate groups of digits before the decimal-point character in formatted nonmonetary quantities.

---

120. The implementation must arrange to encode in a string the various categories due to a heterogeneous locale when `category` has the value `LC_ALL`.

`char *grouping`
A string whose elements indicate the size of each group of digits in formatted nonmonetary quantities.

`char *int_curr_symbol`
The international currency symbol applicable to the current locale. The first three characters contain the alphabetic international currency symbol in accordance with those specified in ISO 4217:1987. The fourth character (immediately preceding the null character) is the character used to separate the international currency symbol from the monetary quantity.

`char *currency_symbol`
The local currency symbol applicable to the current locale.

`char *mon_decimal_point`
The decimal-point used to format monetary quantities.

`char *mon_thousands_sep`
The separator for groups of digits before the decimal-point in formatted monetary quantities.

`char *mon_grouping`
A string whose elements indicate the size of each group of digits in formatted monetary quantities.

`char *positive_sign`
The string used to indicate a nonnegative-valued formatted monetary quantity.

`char *negative_sign`
The string used to indicate a negative-valued formatted monetary quantity.

`char int_frac_digits`
The number of fractional digits (those after the decimal-point) to be displayed in a internationally formatted monetary quantity.

`char frac_digits`
The number of fractional digits (those after the decimal-point) to be displayed in a formatted monetary quantity.

`char p_cs_precedes`
Set to 1 or 0 if the **`currency_symbol`** respectively precedes or succeeds the value for a nonnegative formatted monetary quantity.

`char p_sep_by_space`
Set to 1 or 0 if the **`currency_symbol`** respectively is or is not separated by a space from the value for a nonnegative formatted monetary quantity.

`char n_cs_precedes`
Set to 1 or 0 if the **`currency_symbol`** respectively precedes or succeeds the value for a negative formatted monetary quantity.

`char n_sep_by_space`
Set to 1 or 0 if the **`currency_symbol`** respectively is or is not separated by a space from the value for a negative formatted monetary quantity.

`char p_sign_posn`
Set to a value indicating the positioning of the **`positive_sign`** for a nonnegative formatted monetary quantity.

`char n_sign_posn`
Set to a value indicating the positioning of the **`negative_sign`** for a negative formatted monetary quantity.

[4] The elements of **`grouping`** and **`mon_grouping`** are interpreted according to the following:

`CHAR_MAX` No further grouping is to be performed.

`0` The previous element is to be repeatedly used for the remainder of the digits.

other The integer value is the number of digits that comprise the current group. The next element is examined to determine the size of the next group of digits before the current group.

[5] The value of **`p_sign_posn`** and **`n_sign_posn`** is interpreted according to the following:

`0` Parentheses surround the quantity and **`currency_symbol`**.

`1` The sign string precedes the quantity and **`currency_symbol`**.

`2` The sign string succeeds the quantity and **`currency_symbol`**.

`3` The sign string immediately precedes the **`currency_symbol`**.

`4` The sign string immediately succeeds the **`currency_symbol`**.

[6] The implementation shall behave as if no library function calls the **`localeconv`** function.

Returns

[7] The **`localeconv`** function returns a pointer to the filled-in object. The structure pointed to by the return value shall not be modified by the program, but may be overwritten by a subsequent call to the **`localeconv`** function. In addition, calls to the **`setlocale`** function with categories **`LC_ALL`**, **`LC_MONETARY`**, or **`LC_NUMERIC`** may overwrite the contents of the structure.

Example

[8] The following table illustrates the rules which may well be used by four countries to format monetary quantities.

Country	Positive format	Negative format	International format
Italy	**L.1.234**	**-L.1.234**	**ITL.1.234**
Netherlands	**F 1.234,56**	**F -1.234,56**	**NLG 1.234,56**
Norway	**kr1.234,56**	**kr1.234,56-**	**NOK 1.234,56**
Switzerland	**SFrs.1,234.56**	**SFrs.1,234.56C**	**CHF 1,234.56**

[9] For these four countries, the respective values for the monetary members of the structure returned by **localeconv** are:

	Italy	Netherlands	Norway	Switzerland
int_curr_symbol	**"ITL."**	**"NLG "**	**"NOK "**	**"CHF "**
currency_symbol	**"L."**	**"F"**	**"kr"**	**"SFrs."**
mon_decimal_point	**""**	**","**	**","**	**"."**
mon_thousands_sep	**"."**	**"."**	**"."**	**","**
mon_grouping	**"\3"**	**"\3"**	**"\3"**	**"\3"**
positive_sign	**""**	**""**	**""**	**""**
negative_sign	**"-"**	**"-"**	**"-"**	**"C"**
int_frac_digits	**0**	**2**	**2**	**2**
frac_digits	**0**	**2**	**2**	**2**
p_cs_precedes	**1**	**1**	**1**	**1**
p_sep_by_space	**0**	**1**	**0**	**0**
n_cs_precedes	**1**	**1**	**1**	**1**
n_sep_by_space	**0**	**1**	**0**	**0**
p_sign_posn	**1**	**1**	**1**	**1**
n_sign_posn	**1**	**4**	**2**	**2**

7.6 Mathematics <math.h>

[1] The header **`<math.h>`** declares two types and several mathematical functions and defines several macros. Most synopses specify a function which takes one or two double arguments and returns a double value; for each such function, there are functions with the same name but with f and l suffixes which are corresponding functions with float and long double arguments and return values.[121] Integer arithmetic functions and conversion functions are discussed later.

[2] The types

```
float_t
double_t
```

are floating types at least as wide as **`float`** and **`double`**, respectively, and such that **`double_t`** is at least as wide as **`float_t`**. If **`FLT_EVAL_METHOD`** equals 0, **`float_t`** and **`double_t`** are **`float`** and **`double`**, respectively; if **`FLT_EVAL_METHOD`** equals 1, they are both **`double`**; if **`FLT_EVAL_METHOD`** equals 2, they are both **`long double`**; and for other values of **`FLT_EVAL_METHOD`**, they are otherwise implementation-defined.[122]

[3] The macro

```
HUGE_VAL
```

expands to a positive **`double`** constant expression, not necessarily representable as a **`float`**. The macros

```
HUGE_VALF
HUGE_VALL
```

are respectively **`float`** and **`long double`** analogs of **`HUGE_VAL`**. [123] The macro

```
INFINITY
```

expands to a constant expression of type **`float_t`** representing an implementation-defined positive or unsigned infinity, if available, else to a positive constant of type **`float_t`** that overflows at translation time. The macro

```
NAN
```

is defined if and only if the implementation supports quiet NaNs for the **`float_t`**

---

121. Particularly on systems with wide expression evaluation, the **`<math.h>`** function macros might pass arguments and return values in wider format than the synopsis prototype indicates.

122. The types **`float_t`** and **`double_t`** are intended to be the implementation's most efficient types at least as wide as **`float`** and **`double`**, repectively. For **`FLT_EVAL_METHOD`** equal 0, 1, or 2, the type **`float_t`** is the narrowest type used by the implementation to evaluate floating expressions.

123. **`HUGE_VAL`**, **`HUGE_VALF`**, and **`HUGE_VALL`** can be positive infinities in an implementation that supports infinities.

type. It expands to a constant expression of type **`float_t`** representing an implementation-defined quiet NaN. The macros

```
FP_NAN
FP_INFINITE
FP_NORMAL
FP_SUBNORMAL
FP_ZERO
```

are for number classification. They represent the mutually exclusive kinds of floating-point values. They expand to integral constant expressions with distinct values. The macro

```
DECIMAL_DIG
```

expands to an integral constant expression whose value is implementation-defined. It represents a number of decimal digits supported by conversion between decimal and all internal floating-point formats.[124]

Recommended practice

[4] Conversion from (at least) **`double`** to decimal with **`DECIMAL_DIG`** digits and back is the identity function.[125]

7.6.1 The `FP_CONTRACT` macros

Synopsis

[1] *

```
#include <math.h>
FP_CONTRACT_ON;
FP_CONTRACT_OFF;
FP_CONTRACT_DEFAULT;
```

Description

[2] The **`FP_CONTRACT`** macros can be used to allow (if the state is on) or disallow (if the state is off) the implementation to contract expressions (6.3). Each macro can occur either outside external declarations or preceding all declarations and statements

---

124. **`DECIMAL_DIG`** is intended to give an appropriate number of digits to carry in canonical decimal representations.

125. In order that correctly rounded conversion from an internal floating-point format with precision **`m`** to decimal with **`DECIMAL_DIG`** digits and back be the identity function, **`DECIMAL_DIG`** should be a positive integer **`n`** satisfying the inequality: [**Editor: The following equations need to be fixed.**]

n ≥ m   **if FLT_RADIX is 10**

10n - 1 > FLT_RADIXm   **otherwise**

inside a compound statement. When outside external declarations, the macro takes effect from its occurrence until another **FP_CONTRACT**macro is encountered, or until the end of the translation unit. When inside a compound statement, the macro takes effect from its occurrence until another **FP_CONTRACT** macro is encountered (within a nested compound statement), or until the end of the compound statement; at the end of a compound statement the state for the macros is restored to its condition just before the compound statement. The effect of one of these macros in any other context is undefined. The default state (on or off) for the macros is implementation-defined.

7.6.2 Classification macros

[1] In the synopses in this subclause, floating-type indicates a parameter of the same floating type as the argument. The result is undefined if an argument is not of floating type.

7.6.2.1 The `fpclassify` macro

Synopsis

[1]

```
#include <math.h>
int fpclassify(floating-type x);
```

Description

[2] The **fpclassify** macro classifies its argument value as NaN, infinite, normal, subnormal, or zero. First, an argument represented in a format wider than its semantic type is converted to its semantic type. Then classification is based on the type of the argument.[126]

Returns

[3] The **fpclassify** macro returns the value of the number classification macro appropriate to the value of its argument.

Example

[4] The **fpclassify** macro might be implemented in terms of ordinary functions as

126. Since an expression can be evaluated with more range and precision than its type has, it is important to know the type that classification is based on. For example, a normal **long double** value might become subnormal when converted to **double**, and zero when converted to **float**.

```
#define fpclassify(x) \
        ((sizeof(x) == sizeof(float)) ? \
       __fpclassifyf(x) \
        : (sizeof(x) == sizeof(double)) ? \
       __fpclassifyd(x) \
        : __fpclassifyl(x))
```

7.6.2.2 The `signbit` macro

Synopsis

[1]

```
#include <math.h>
int signbit(floating-type x);
```

Description

[2] The **`signbit`** macro determines whether the sign of its argument value is negative.[127]

Returns

[3] The **`signbit`** macro returns a nonzero value if and only if the sign of its argument value is negative.

7.6.2.3 The `isfinite` macro

Synopsis

[1]

```
#include <math.h>
int isfinite(floating-type x);
```

Description

[2] The **`isfinite`** macro determines whether its argument has a finite value (zero, subnormal, or normal, and not infinite or NaN). First, an argument represented in a format wider than its semantic type is converted to its semantic type. Then determination is based on the type of the argument.

Returns

[3] The **`isfinite`** macro returns a nonzero value if and only if its argument has a finite value.

127. The **`signbit`** macro faithfully reports the sign of all values, including infinities, zeros, and NaNs.

7.6.2.4 The `isnormal` macro

Synopsis

[1]

```
#include <math.h>
int isnormal(floating-type x);
```

Description

[2] The **`isnormal`** macro determines whether its argument value is normal (neither zero, subnormal, infinite, nor NaN). First, an argument represented in a format wider than its semantic type is converted to its semantic type. Then determination is based on the type of the argument.

Returns

[3] The **`isnormal`** macro returns a nonzero value if and only if its argument has a normal value.

7.6.2.5 The `isnan` macro

Synopsis

[1]

```
#include <math.h>
int isnan(floating-type x);
```

Description

[2] The **`isnan`** macro determines whether its argument value is a NaN. First, an argument represented in a format wider than its semantic type is converted to its semantic type. Then determination is based on the type of the argument.[128]

Returns

[3] The **`isnan`** macro returns a nonzero value if and only if its argument has a NaN value.

128. The type for determination doesn't matter unless the implementation supports NaNs in the evaluation type but not in the semantic type.

7.6.3 Treatment of error conditions

[1] The behavior of each of the functions in **<math.h>** is defined for all representable values of its input arguments.

[2] For all functions, a *domain error* occurs if an input argument is outside the domain over which the mathematical function is defined. The description of each function lists any required domain errors; an implementation may define additional domain errors, provided that such errors are consistent with the mathematical definition of the function.[129] On a domain error, the function returns an implementation-defined value; whether the integer expression errno acquires the value **EDOM** is implementation-defined.

[3] Similarly, a range error occurs if the mathematical result of the function cannot be represented in an object of the specified type, due to extreme magnitude. A floating result overflows if the magnitude of the mathematical result is finite but so large that the mathematical result cannot be represented, without extraordinary roundoff error, in an object of the specified type. If a floating result overflows and default rounding is in effect, or if the mathematical result is an exact infinity (for example **log(0.0)**), then the function returns the value of the macro **HUGE_VAL**, **HUGE_VALF**, or **HUGE_VALL** appropriate to the specified result type, with the same sign as the correct value of the function; whether errno acquires the value **ERANGE** when a range error occurs is implementation-defined. The result underflows if the magnitude of the mathematical result is so small that the mathematical result cannot be represented, without extraordinary roundoff error, in an object of the specified type.[130] If the result underflows, the function returns a value whose magnitude is no greater than the smallest normalized positive number in the specified type and is otherwise implementation-defined; whether errno acquires the value **ERANGE** is implementation-defined.

129. In an implementation that supports infinities, this allows an infinity as an argument to be a domain error if the mathematical domain of the function does not include the infinity.

130. The term underflow here is intended to encompass both *gradual underflow* as in IEC 559 and also *flush-to-zero* underflow.

7.6.4 Trigonometric functions

7.6.4.1 The `acos` function

Synopsis

[1]

```
#include <math.h>
double acos(double x);
```

Description

[2] The **`acos`** function computes the principal value of the arc cosine of **`x`**. A domain error occurs for arguments not in the range $[-1, +1]$.

Returns

[3] The **`acos`** function returns the arc cosine in the range $[0, \pi]$ radians.

7.6.4.2 The `asin` function

Synopsis

[1]

```
#include <math.h>
double asin(double x);
```

Description

[2] The **`asin`** function computes the principal value of the arc sine of **`x`**. A domain error occurs for arguments not in the range $[-1, +1]$.

Returns

[3] The **`asin`** function returns the arc sine in the range $[-\pi/2, +\pi/2]$ radians.

7.6.4.3 The `atan` function

Synopsis

[1]

```
#include <math.h>
double atan(double x);
```

Description

[2] The **`atan`** function computes the principal value of the arc tangent of **`x`**.

Returns

[3] The **`atan`** function returns the arc tangent in the range $[-\pi/2, +\pi/2]$ radians.

7.6.4.4 The `atan2` function

Synopsis

[1]

```
#include <math.h>
double atan2(double y, double x);
```

Description

[2] The **`atan2`** function computes the principal value of the arc tangent of **`y/x`**, using the signs of both arguments to determine the quadrant of the return value. A domain error may occur if both arguments are zero.

Returns

[3] The **`atan2`** function returns the arc tangent of **`y/x`**, in the range $[-\pi, +\pi]$ radians.

7.6.4.5 The `cos` function

Synopsis

[1]

```
#include <math.h>
double cos(double x);
```

Description

[2] The **`cos`** function computes the cosine of **`x`** (measured in radians).

Returns

[3] The **`cos`** function returns the cosine value.

7.6.4.6 The `sin` function

Synopsis

[1]

```
#include <math.h>
double sin(double x);
```

Description

[2] The **`sin`** function computes the sine of **`x`** (measured in radians).

Returns

[3] The **`sin`** function returns the sine value.

7.6.4.7 The `tan` function

Synopsis

[1]

```
#include <math.h>
double tan(double x);
```

Description

[2] The **`tan`** function returns the tangent of **`x`** (measured in radians).

Returns

[3] The **`tan`** function returns the tangent value.

7.6.5 Hyperbolic functions

7.6.5.1 The `cosh` function

Synopsis

[1]

```
#include <math.h>
double cosh(double x);
```

Description

[2] The **`cosh`** function computes the hyperbolic cosine of **`x`**. A range error occurs if the magnitude of **`x`** is too large.

Returns

[3] The **`cosh`** function returns the hyperbolic cosine value.

7.6.5.2 The `sinh` function

Synopsis

[1]

```
#include <math.h>
double sinh(double x);
```

Description

[2] The **`sinh`** function computes the hyperbolic sine of **`x`**. A range error occurs if the magnitude of **`x`** is too large.

Returns

[3] The **`sinh`** function returns the hyperbolic sine value.

7.6.5.3 The `tanh` function

Synopsis

[1]

```
#include <math.h>
double tanh(double x);
```

Description

[2] The **`tanh`** function computes the hyperbolic tangent of **`x`**.

Returns

[3] The **`tanh`** function returns the hyperbolic tangent value.

7.6.5.4 The `acosh` function

Synopsis

[1]

```
#include <math.h>
double acosh(double x);
```

Description

[2] The **`acosh`** function computes the (nonnegative) arc hyperbolic cosine of **`x`**. A domain error occurs for arguments less than 1.

Returns

[3] The **`acosh`** function returns the arc hyperbolic cosine in the range $[0, +\pi]$.

7.6.5.5 The `asinh` function

Synopsis

[1]

```
#include <math.h>
double asinh(double x);
```

Description

[2] The **`asinh`** function computes the arc hyperbolic sine of x.

Returns

[3] The **`asinh`** function returns the arc hyperbolic sine.

7.6.5.6 The **atanh** function

Synopsis

[1]

```
#include <math.h>
double atanh(double x);
```

Description

[2] The **atanh** function computes the arc hyperbolic tangent of **x**. A domain error occurs for arguments not in the range [-1, +1]. HU "Returns"

[3] The **atanh** function returns the arc hyperbolic tangent.

7.6.6 Exponential and logarithmic functions

7.6.6.1 The **exp** function

Synopsis

[1]

```
#include <math.h>
double exp(double x);
```

Description

[2] The **exp** function computes the exponential function of **x**. A range error occurs if the magnitude of **x** is too large.

Returns

[3] The **exp** function returns the exponential value.

7.6.6.2 The **frexp** function

Synopsis

[1]

```
#include <math.h>
double frexp(double value, int *exp);
```

Description

[2] The **frexp** function breaks a floating-point number into a normalized fraction and an integral power of 2. It stores the integer in the **int** object pointed to by **exp**.

Returns

[3] The **frexp** function returns the value **x**, such that **x** is a **double** with magnitude in the interval [1/2, 1) or zero, and **value** equals **x** times 2 raised to the power ***exp**. If **value** is zero, both parts of the result are zero.

7.6.6.3 The `ldexp` function

Synopsis

[1]

```
#include <math.h>
double ldexp(double x, int exp);
```

Description

[2] The **`ldexp`** function multiplies a floating-point number by an integral power of 2. A range error may occur.

Returns

[3] The **`ldexp`** function returns the value of **`x`** times 2 raised to the power **`exp`**.

7.6.6.4 The `log` function

Synopsis

[1]

```
#include <math.h>
double log(double x);
```

Description

[2] The **`log`** function computes the natural logarithm of **`x.`** A domain error occurs if the argument is negative. A range error may occur if the argument is zero.

Returns

[3] The **`log`** function returns the natural logarithm.

7.6.6.5 The `log10` function

Synopsis

[1]

```
#include <math.h>
double log10(double x);
```

Description

[2] The **`log10`** function computes the base-ten logarithm of **`x`**. A domain error occurs if the argument is negative. A range error may occur if the argument is zero.

Returns

[3] The **`log10`** function returns the base-ten logarithm.

7.6.6.6 The `modf` function

Synopsis

[1]

```
#include <math.h>
double modf(double value, double *iptr);
```

Description

[2] The **`modf`** function breaks the argument **`value`** into integral and fractional parts, each of which has the same sign as the argument. It stores the integral part as a **`double`** in the object pointed to by **`iptr`**.

Returns

[3] The **`modf`** function returns the signed fractional part of **`value`**.

7.6.6.7 The `exp2` function

Synopsis

[1]

```
#include <math.h>
double exp2(double x);
```

Description

[2] The **`exp2`** function computes the base-2 exponential of **`x`**: **`2x`**. [131] A range error occurs if the magnitude of **`x`** is too large.

Returns

[3] The **`exp2`** function returns the base-2 exponential.

7.6.6.8 The `expm1` function

Synopsis

[1]

```
#include <math.h>
double expm1(double x);
```

Description

[2] The **`expm1`** function computes the base-e exponential of the argument, minus 1: **`ex - 1`**. A range error occurs if the **`x`** is too large.

---

131. For small magnitude **`x`**, **`expm1(x)`** is expected to be more accurate than **`exp(x) - 1`**.

Returns

[3] The **`expm1`** function returns **`ex - 1`**.

7.6.6.9 The `log1p` function

Synopsis

[1]

```
#include <math.h>
double log1p(double x);
```

Description

[2] The **`log1p`** function computes the base-e logarithm of 1 plus the argument.[132] A domain error occurs if the argument is less than -1. A range error may occur if the argument equals -1.

Returns

[3] The **`log1p`** function returns the base-e logarithm of 1 plus the argument.

7.6.6.10 The `log2` function

Synopsis

[1]

```
#include <math.h>
double log2(double x);
```

Description

[2] The **`log2`** function computes the base-2 logarithm of **`x`**. A domain error occurs if the argument is less than zero. A range error may occur if the argument is zero.

Returns

[3] The **`log2`** function returns the base-2 logarithm.

7.6.6.11 The `logb` function

Synopsis

[1]

```
#include <math.h>
double logb(double x);
```

Description

132. For small magnitude **`x`**, **`log1p(x)`** is expected to be more accurate than **`log(1 + x)`**.

[2] The `logb` function extracts the exponent of `x`, as a signed integral value in the format of `x`. If `x` is subnormal it is treated as though it were normalized; thus for positive finite `x`,

```
1  ≤  x * FLT_RADIX-logb(x)  <  FLT_RADIX
```

A range error may occur if the argument is zero.

Returns

[3] The `logb` function returns the signed exponent of its argument.

7.6.6.12 The `scalb` function

Synopsis

[1]

```
#include <math.h>
double scalb(double x, long int n);
```

Description

[2] The `scalb` function computes `x * FLT_RADIXn` efficiently, not normally by computing `FLT_RADIXn` explicitly. A range error may occur.

Returns

[3] The `scalb` function returns `x * FLT_RADIXn`.

7.6.7 Power functions and absolute value functions

7.6.7.1 The `pow` function

Synopsis

[1]

```
#include <math.h>
double pow(double x, double y);
```

Description

[2] The `pow` function computes `x` raised to the power `y`. A domain error occurs if `x` is negative and `y` is finite and not an integral value. A domain error occurs if the result cannot be represented when `x` is zero and `y` is less than or equal to zero. A range error may occur.

Returns

[3] The `pow` function returns the value of `x` raised to the power `y`.

7.6.7.2 The `sqrt` function

Synopsis

[1]

```
#include <math.h>
double sqrt(double x);
```

Description

[2] The **`sqrt`** function computes the nonnegative square root of **`x`**. A domain error occurs if the argument is negative.

Returns

[3] The **`sqrt`** function returns the value of the square root.

7.6.7.3 The `hypot` function

Synopsis

[1]

```
#include <math.h>
double hypot(double x, double y);
```

Description

[2] The **`hypot`** function computes the square root of the sum of the squares of **`x`** and **`y`**, without undue overflow or underflow. A range error may occur.

[3]

Returns

[4] The **`hypot`** function returns the square root of the sum of the squares of **`x`** and **`y`**.

7.6.8 Error and gamma functions

[1]

7.6.8.1 The `erf` function

Synopsis

[1]

```
#include <math.h>
double erf(double x);
```

Description

[2] The **`erf`** function computes the error function of **`x`**.

Returns

[3] The **`erf`** function returns the error function of **`x`**.

7.6.8.2 The `erfc` function

Synopsis

[1]

```
#include <math.h>
double erfc(double x);
```

Description

[2] The **`erfc`** function computes the complementary error function of **`x`**. A range error occurs if **`x`** is too large.

Returns

[3] The **`erfc`** function returns the complementary error function of **`x`**.

7.6.8.3 The `gamma` function

Synopsis

[1]

```
#include <math.h>
double gamma(double x);
```

Description

[2] The **`gamma`** function computes the gamma function of **`x`**: **`G(x)`**. A domain error occurs if **`x`** is a negative integer or zero. A range error may occur if the magnitude of **`x`** is too large.

Returns

[3] The **`gamma`** function returns **`G(x)`**.

7.6.8.4 The `lgamma` function

Synopsis

[1]

```
#include <math.h>
double lgamma(double x);
```

Description

[2] The **`lgamma`** function computes the logarithm of the absolute value of gamma of **`x`**: **`loge(|G(x)|)`**. A range error occurs if **`x`** is too large or if **`x`** is a negative integer or zero.

Returns

[3] The **`lgamma`** function returns **`loge(|G(x)|)`**.

7.6.9 Nearest integer and absolute value functions

7.6.9.1 The `ceil` function

Synopsis

[1]

```
#include <math.h>
double ceil(double x);
```

Description

[2] The **`ceil`** function computes the smallest integral value not less than **`x`**.

Returns

[3] The **`ceil`** function returns the smallest integral value not less than **`x`**, expressed as a double.

7.6.9.2 The `fabs` function

Synopsis

[1]

```
#include <math.h>
double fabs(double x);
```

Description

[2] The **`fabs`** function computes the absolute value of a floating-point number **`x`**.

Returns

[3] The **`fabs`** function returns the absolute value of **`x.`**

7.6.9.3 The `floor` function

Synopsis

[1]

```
#include <math.h>
double floor(double x);
```

Description

[2] The **`floor`** function computes the largest integral value not greater than **`x`**.

Returns

[3] The **`floor`** function returns the largest integral value not greater than **`x`**, expressed as a double.

7.6.9.4 The `nearbyint` function

Synopsis

[1]

```
#include <math.h>
double nearbyint(double x);
```

Description

[2] The **`nearbyint`** function differs from the **`rint`** function (7.6.9.4) only in that the **`nearbyint`** function does not raise the inexact exception. (See X.10.6.3-4.)

Returns

[3] The **`nearbyint`** function returns the rounded integral value.

7.6.9.5 The `rint` function

Synopsis

[1]

```
#include <math.h>
double rint(double x);
```

Description

[2] The **`rint`** function rounds its argument to an integral value in floating-point format, using the current rounding direction.

Returns

[3] The **`rint`** function returns the rounded integral value.

7.6.9.6 The `rinttol` function

Synopsis

[1]

```
#include <math.h>
long int rinttol(long double x);
```

Description

[2] The **`rinttol`** function rounds its argument to the nearest integral value, rounding according to the current rounding direction. If the rounded value is outside the range of long int, the numeric result is unspecified. A range error may occur if the magnitude of **`x`** is too large.

Returns

[3] The **`rinttol`** function returns the rounded **`long`**int value, using the current rounding direction.

7.6.9.7 The `rinttoll` function

Synopsis

[1]

```
#include <math.h>
long long rinttoll(long double x);
```

Description

[2] The **`rinttoll`** function is equivalent to the **`rintol`** function, except that the returned value has type **`long long`**.

7.6.9.8 The `round` function

Synopsis

[1]

```
#include <math.h>
double round(double x);
```

[2] The **`round`** function rounds its argument to the nearest integral value in floating-point format, rounding halfway cases away from zero, regardless of the current rounding direction.

Returns

[3] The **`round`** function returns the rounded integral value.

7.6.9.9 The `roundtol` function

Synopsis

[1]

```
#include <math.h>
long int roundtol(long double x);
```

Description

[2] The **`roundtol`** function rounds its argument to the nearest integral value, rounding halfway cases away from zero, regardless of the current rounding direction. If the rounded value is outside the range of long int, the numeric result is unspecified. A range error may occur if the magnitude of **`x`** is too large.

Returns

[3] The **`roundtol`** function returns the rounded **`long int`** value.

7.6.9.10 The `roundtoll` function

Synopsis

[1]

```
#include <math.h>
long long roundtoll(long double x);
```

Description

[2] The **roundtoll** function is equivalent to the **roundtol** function, except that the returned value has type **long long**.

7.6.9.11 The `trunc` function

Synopsis

[1]

```
#include <math.h>
double trunc(double x);
```

Description

[2] The **trunc** function rounds its argument to the integral value, in floating format, nearest to but no larger in magnitude than the argument.

Returns

[3] The **trunc** function returns the truncated integral value.

7.6.10 Remainder functions

7.6.10.1 The `fmod` function

Synopsis

[1]

```
#include <math.h>
double fmod(double x, double y);
```

Description

[2] The **fmod** function computes the floating-point remainder of **x/y**.

Returns

[3] The **fmod** function returns the value $\mathbf{x} - i * \mathbf{y}$, for some integer i such that, if **y** is nonzero, the result has the same sign as **x** and magnitude less than the magnitude of **y**. If **y** is zero, whether a domain error occurs or the **fmod** function returns zero is implementation-defined.

7.6.10.2 The `remainder` function

Synopsis

[1]

```
#include <math.h>
double remainder(double x, double y);
```

Description

[2] The **`remainder`** function computes the remainder **`x REM y`** required by IEC 559.[133]

Returns

[3] The **`remainder`** function returns **`x REM y`**.

7.6.10.3 The `remquo` function

Synopsis

[1]

```
#include <math.h>
double remquo(double x, double y, int *quo);
```

Description

[2] The **`remquo`** function computes the same remainder as the **`remainder`** function. In the object pointed to by **`quo`**it**`stores`**a**`value`**whose sign is the sign of **`x/y`** and whose magnitude is congruent **`mod`**2n to the magnitude of the integral quotient of **`x/y`**, where **`n`** is an implementation-defined integer at least 3.

Returns

[3] The **`remquo`** function returns **`x REM y`**.

---

133. ‘‘When **`y != 0`**, the remainder **`r = x REM y`** is defined regardless of the rounding mode by the mathematical relation **`r = x - y * n`**, where **`n`** is the integer nearest the exact value of **`x/y`**; whenever **`|n - x/y | = 1/2`**, then **`n`** is even. Thus, the remainder is always exact. If **`r = 0`**, its sign shall be that of **`x`**.’’ This definition is applicable for all implementations.

7.6.11 Manipulation functions

7.6.11.1 The `copysign` function

Synopsis

[1]

```
#include <math.h>
double copysign(double x, double y);
```

Description

[2] The **`copysign`** function produces a value with the magnitude of **`x`** and the sign of **`y`**. It produces a NaN (with the sign of **`y`**) if **`x`** is a NaN. On implementations that represent a signed zero but do not treat negative zero consistently in arithmetic operations, the **`copysign`** function regards the sign of zero as positive.

Returns

[3] The **`copysign`** function returns a value with the magnitude of **`x`** and the sign of **`y`**.

7.6.11.2 The `nan` function

Synopsis

[1]

```
#include <math.h>
double nan(const char *tagp);
```

Description

[2] If the implementation supports quiet NaNs for the **`double`** type, then the call **`nan("n-char-sequence")`** is equivalent to **`strtod("NAN(n-char-sequence)", (char**) NULL)`**; the call **`nan("")`** is equivalent to **`strtod("NAN()", (char**) NULL)`**. If **`tagp`** does not point to an *n-char-sequence* string then the result NaN's content is unspecified. If the implementation does not support quiet NaNs for the **`double`** type, a call to the **`nan`** function is unspecified.

Returns

[3] The **`nan`** function returns a quiet NaN, if available, with content indicated through **`tagp`**.

7.6.11.3 The `nextafter` function

Synopsis

[1]

```
#include <math.h>
double nextafter(double x, double y);
```

Description

[2] The **`nextafter`** function determines the next representable value, in the type of the function, after **`x`** in the direction of **`y`**, where **`x`** and **`y`** are first converted to the type of the function.[134] The **`nextafter`** function returns **`y`** if **`x == y`**.

Returns

[3] The function **`nextafter`** returns the next representable value in the specified format after **`x`** in the direction of **`y`**.

7.6.12 Maximum, minimum, and positive difference functions

7.6.12.1 The `fdim` function

Synopsis

[1]

```
#include <math.h>
double fdim(double x, double y);
```

Description

[2] The **`fdim`** function determines the positive difference between its arguments:

```
x - y          if x > y
+0             if x ≤ y
```

A range error may occur.

Returns

[3] The **`fdim`** function returns the positive difference between **`x`** and **`y`**.

134. The argument values are converted to the type of the function, even by a macro implementation of the function.

7.6.12.2 The `fmax` function

Synopsis

[1]

```
#include <math.h>
double fmax(double x, double y);
```

Description

[2] The **`fmax`** function determines the maximum numeric value of its arguments.[135]

Returns

[3] The **`fmax`** function returns the maximum numeric value of its arguments.[136]

7.6.12.3 The `fmin` function

Synopsis

[1]

```
#include <math.h>
double fmin(double x, double y);
```

Description

[2] The **`fmin`** function determines the minimum numeric value of its arguments.

Returns

[3] The function returns the minimum numeric value of its arguments.

7.6.13 Comparison macros

[1] The relational and equality operators support the usual mathematical relationships between numeric values. For any ordered pair of numeric values exactly one of the relationships less, greater, and equal-is true. Relational operators may raise the invalid exception when argument values are NaNs. For a NaN and a numeric value, or for two NaNs, just the unordered relationship is true.[137] The following subclauses provide macros that are quiet (non exception raising) versions of the relational operators, and other comparison macros that facilitate writing efficient code that accounts for NaNs without suffering the invalid exception.

---

135. NaN arguments are treated as missing data: if one argument is a NaN and the other numeric, then **`fmax`** chooses the numeric value. See X.10.9.2.

136. **`fmin`** is analogous to **`fmax`** in its treatment of NaNs.

137. IEC 559 requires that the built-in relational operators raise the invalid exception if the operands compare unordered, as an error indicator for programs written without consideration of NaNs; the result in these cases is false.

7.6.13.1 The `isgreater` macro

Synopsis

[1]

```
#include <math.h>
int isgreater(floating-expr x, floating-expr y);
```

Description

[2] The **`isgreater`** macro determines whether its first argument is greater than its second argument. The value of **`isgreater(x,y)`** is always equal to **`(x) > (y)`**; however unlike **`(x) > (y)`**, **`isgreater(x,y)`** does not raise the invalid exception when **`x`** and **`y`** are unordered.

Returns

[3] The **`isgreater`** macro returns the value of **`(x) > (y)`**.

7.6.13.2 The `isgreaterequal` macro

Synopsis

[1]

```
#include <math.h>
int isgreaterequal(floating-expr x, floating-expr y);
```

Description

[2] The **`isgreaterequal`** macro determines whether its first argument is greater than or equal to its second argument. The value of **`isgreaterequal(x,y)`** is always equal to **`(x) >= (y)`**; however, unlike **`(x) >= (y)`**, **`isgreaterequal(x,y)`** does not raise the invalid exception when **`x`** and **`y`** are unordered.

Returns

[3] The **`isgreaterequal`** macro returns the value of **`(x) >= (y)`**.

7.6.13.3 The `isless` macro

Synopsis

[1]

```
#include <math.h>
int isless(floating-expr x, floating-expr y);
```

Description

[2] The **`isless`** macro determines whether its first argument is less than its second argument. The value of **`isless(x,y)`** is always equal to **`(x) < (y)`**; however, unlike **`(x) < (y)`**, **`isless(x,y)`** does not raise the invalid exception when **`x`** and **`y`** are unordered.

Returns

[3] The **`isless`** macro returns the value of **`(x) < (y)`**.

7.6.13.4 The `islessequal` macro

Synopsis

[1]

```
#include <math.h>
int islessequal(floating-expr x, floating-expr y);
```

Description

[2] The **`islessequal`** macro determines whether its first argument is less than or equal to its second argument. The value of **`islessequal(x,y)`** is always equal to **`(x) <= (y)`**; however, unlike **`(x) <= (y)`**, **`islessequal(x,y)`** does not raise the invalid exception when **`x`** and **`y`** are unordered.

Returns

[3] The **`islessequal`** macro returns the value of **`(x) <= (y)`**.

7.6.13.5 The `islessgreater` macro

Synopsis

[1]

```
#include <math.h>
int islessgreater(floating-expr x, floating-expr y);
```

Description

[2] The **`islessgreater`** macro determines whether its first argument is less than or greater than its second argument. The **`islessgreater(x,y)`** macro is equivalent to **`(x) < (y) || (x) > (y)`**; however, **`islessgreater(x,y)`** does not raise the invalid exception when **`x`** and **`y`** are unordered (nor does it evaluate **`x`** and **`y`** twice).

Returns

[3] The **`islessgreater`** macro returns the value of **`(x) < (y) || (x) > (y)`**.

7.6.13.6 The `isunordered` macro

Synopsis

[1]

```
#include <math.h>
int isunordered(floating-expr x, floating-expr y);
```

Description

[2] The **`isunordered`** macro determines whether its arguments are unordered.

Returns

[3] The **`isunordered`** macro returns 1 if its arguments are unordered and 0 otherwise.

7.7 Complex arithmetic `<complex.h>`

[1] The header **`<complex.h>`** defines macros and declares functions that support complex arithmetic. Each synopsis specifies a function with one or two double complex parameters and returning a double complex or double value; for each such function, there are similar functions with the same name but with **`f`** and **`l`** suffixes. The **`f`** suffix indicates that (instead of **`double`**) is the corresponding real type for the parameters and result. Similarly the **`l`** suffix indicates that **`long`**double is the corresponding real type for the parameters and result.

[2] The macro

```
_Imaginary_I
```

expands to an expression with a const-qualified type whose corresponding real type is the narrowest real floating type used for expression evaluation,[138] and with the value of the imaginary unit.[139] The macro is suitable for use in constant expressions.[140]

[3] The macro

```
I
```

is defined to be **`_Imaginary_I`**. Notwithstanding the provisions of subclause 7.1.3, it is permitted to undefine the macro **`I`**.

7.7.1 The `CX_LIMITED_RANGE` macros

Synopsis

[1]

```
#include <complex.h>
CX_LIMITED_RANGE_ON;
CX_LIMITED_RANGE_OFF;
CX_LIMITED_RANGE_DEFAULT;
```

Description

The usual mathematical formula for multiplication of two complex numbers and the one for division by a complex number are problematic because of their treatment of infinities and because of undue overflow and underflow. The **`CX_LIMITED_RANGE`** macros can be used to inform the implementation that (where the state is on) the usual mathematical formulas for multiplication and division are acceptable.[141] Each macro

---

138. If **`FLT_EVAL_METHOD`** equals **`0`**, **`1`**, or **`2`**, then **`_Imaginary_I`** has the corresponding real type **`float`**, **`double`**, or **`long`**double**,** respectively.

139. The imaginary unit is a number **`i`** such that **`i*i = -1`**.

140. For those implementations that do not support imaginary types (specified in Annex Y), the macro **`_Imaginary_I`** is intended to have a complex type.

141. The purpose of the macros is to allow the implementation to use the formulas

[**Editor: The following equations need to be fixed.**]

can occur either outside external declarations or preceding all declarations and statements inside a compound statement. When outside external declarations, the macro takes effect from its occurrence until another macro is encountered, or until the end of the translation unit. When inside a compound statement, the macro takes effect from its occurrence until another **`CX_LIMITED_RANGE`** macro is encountered, or until the end of the translation unit. When inside a compound statement, the macro takes effect from its occurrence until another **`CX_LIMITED_RANGE`** macro is encountered (within a nested compound statement), or until the end of the compound statement; at the end of a compound statement the state for the macros is restored to its condition just before the compound statement. The effect of one of these macros in any other context is undefined. The default state for the macros is off.

7.7.2 Complex functions

[1] Values are interpreted as radians, not degrees. An implementation may set errno but is not required to.

7.7.2.1 Branch cuts

[1] Some of the functions below have branch cuts, across which the function is discontinuous. For implementations with a signed zero (including all IEC 559 implementations) that follow the specification of Annex Y, the sign of zero distinguishes one side of a cut from another so the function is continuous (except for format limitations) as the cut is approached from either side. For example, for the square root function, which has a branch cut along the negative real axis, the top of the cut, with imaginary part **`+0`**, maps to the positive imaginary axis, and the bottom of the cut, with imaginary part **`-0,`** maps to the negative imaginary axis.

[2] Implementations that do not support a signed zero (see Annex X) cannot distinguish the sides of branch cuts. These implementations must map a cut so the function is continuous as the cut is approached coming around the finite endpoint of the cut in a counter clockwise direction. (Branch cuts for the functions specified here have just one finite endpoint.) For example, for the square root function, coming counter clockwise around the finite endpoint of the cut along the negative real axis approaches the cut from above, so the cut maps to the positive imaginary axis.

(x + y*I) * (u + v*I) = (x*u - y*v) + (y*u + x*v)*I

(x + y*I) / (u + v*I) = (x*u + y*v) / (u*u + v*v) + ((y*u - x*v) / (u*u + v*v))*I

where the programmer can determine they are safe.

7.7.2.2 The cacos function

Synopsis

[1]

```
#include <complex.h>
double complex cacos(double complex z);
```

Description

[2] The **cacos** function computes the complex arc cosine of **z,** with branch cuts outside the interval **[-1, 1]** along the real axis.

Returns

[3] The **cacos** function returns the complex arc cosine of **z**, in the range of a strip mathematically unbounded along the imaginary axis and in the interval **[0, π]** along **the** real **axis.**

7.7.2.3 The casin function

Synopsis

[1]

```
#include <complex.h>
double complex casin(double complex z);
```

Description

[2] The **casin** function computes the complex arc sine of **z**, with branch cuts outside the interval **[-1, 1]** along the real axis.

Returns

[3] The **casin** function returns the complex arc sine of **z**, in the range of a strip mathematically unbounded along the imaginary axis and in the interval **[-π/2, π/2]** along the real axis.

7.7.2.4 The catan function

Synopsis

[1]

```
#include <complex.h>
double complex catan(double complex z);
```

Description

[2] The **catan** function computes the complex arc tangent of **z**, with branch cuts outside the interval **[-i, i]** along the imaginary axis.

Returns

[3] The **catan** function returns the complex arc tangent of **z**, in the range of a strip mathematically unbounded along the imaginary axis and in the interval **`[-π/2, π/2] along the`** real axis.

7.7.2.5 The `ccos` function

Synopsis

[1]

```
#include <complex.h>
double complex ccos(double complex z);
```

Description

[2] The **`ccos`** function computes the complex cosine of **`z`**.

Returns

[3] The **`ccos`** function returns the complex cosine of **`z`**.

7.7.2.6 The `csin` function

Synopsis

[1]

```
#include <complex.h>
double complex csin(double complex z);
```

Description

[2] The **`csin`** function computes the complex sine of **`z`**.

Returns

[3] The **`csin`** function returns the complex sine of **`z`**.

7.7.2.7 The `ctan` function

Synopsis

[1]

```
#include <complex.h>
double complex ctan(double complex z);
```

Description

[2] The **`ctan`** function computes the complex tangent of **`z`**.

Returns

[3] The **`ctan`** function returns the complex tangent of **`z`**.

7.7.2.8 The `cacosh` function

Synopsis

[1]

```
#include <complex.h>
double complex cacosh(double complex z);
```

Description

[2] The **`cacosh`** function computes the complex arc hyperbolic cosine of **`z`**, with a branch cut at values less than **`1`** along the real axis.

Returns

[3] The **`cacosh`** function returns the complex arc hyperbolic cosine of **`z`**, in the range of a half-strip of non-negative values along the real axis and in the interval **`[-iπ, iπ]`** along the imaginary axis.

7.7.2.9 The `casinh` function

Synopsis

[1]

```
#include <complex.h>
double complex casinh(double complex z);
```

Description

[2] The **`casinh`** function computes the complex arc hyperbolic sine of **`z`**, with branch cuts outside the interval **`[-i, i]`** along the imaginary axis.

Returns

[3] The **`casinh`** function returns the complex arc hyperbolic sine of **`z`**, in the range of a strip mathematically unbounded along the real axis and in the interval **`[-iπ/2, iπ/2]`** along the imaginary axis.

7.7.2.10 The `catanh` function

Synopsis

[1]

```
#include <complex.h>
double complex catanh(double complex z);
```

Description

[2] The **`catanh`** function computes the complex arc hyperbolic tangent of **`z`**, with branch cuts outside the interval **`[-1, 1]`** along the real axis.

Returns

[3] The **`catanh`** function returns the complex arc hyperbolic tangent of **`z`**, in the range of a strip mathematically unbounded along the real axis and in the interval **[-iπ/2, iπ/2]** along the imaginary axis.

7.7.2.11 The `ccosh` function

Synopsis

[1]

```
#include <complex.h>
double complex ccosh(double complex z);
```

Description

[2] The **ccosh** function computes the complex hyperbolic cosine of **z**.

Returns

[3] The **ccosh** function returns the complex hyperbolic cosine of **z**.

7.7.2.12 The `csinh` function

Synopsis

[1]

```
#include <complex.h>
double complex csinh(double complex z);
```

Description

[2] The **csinh** function computes the complex hyperbolic sine of **z**.

Returns

[3] The **csinh** function returns the complex hyperbolic sine of **z**.

7.7.2.13 The `ctanh` function

Synopsis

[1]

```
#include <complex.h>
double complex ctanh(double complex z);
```

Description

[2] The **ctanh** function computes the complex hyperbolic tangent of **z**.

Returns

[3] The **ctanh** function returns the complex hyperbolic tangent of **z**.

7.7.2.14 The `cexp` function

Synopsis

[1]

```
#include <complex.h>
double complex cexp(double complex z);
```

Description

[2] The **`cexp`** function computes the complex base-e exponential of **`z`**.

Returns

[3] The **`cexp`** function returns the complex base-e exponential of **`z`**.

7.7.2.15 The `clog` function

Synopsis

[1]

```
#include <complex.h>
double complex clog(double complex z);
```

Description

[2] The **`clog`** function computes the complex natural (base-e) logarithm of **`z`**, with a branch cut along the negative real axis.

Returns

[3] The **`clog`** function returns the complex natural logarithm of **`z`**, in the range of a strip mathematically unbounded along the real axis and in the interval **`[-i`**π**`, i`**π**`]`** along the imaginary axis.

7.7.2.16 The `csqrt` function

Synopsis

[1]

```
#include <complex.h>
double complex csqrt(double complex z);
```

Description

[2] The **`csqrt`** function computes the complex square root of **`z`**, with a branch cut along the negative real axis.

Returns

[3] The **`csqrt`** function returns the complex square root of **`z`**, in the range of the right half-plane (including the imaginary axis).

7.7.2.17 The `cabs` function

Synopsis

[1]

```
#include <complex.h>
double cabs(double complex z);
```

Description

[2] The **`cabs`** function computes the complex absolute value (also called norm, modulus, or magnitude) of **`z`**.

Returns

[3] The **`cabs`** function returns the complex absolute value of **`z`**.

7.7.2.18 The `cpow` function

Synopsis

[1]

```
#include <complex.h>
double complex cpow(double complex x, double complex y);
```

Description

[2] The **`cpow`** function computes the complex power function **`xy`**, with a branch cut for the first parameter along the negative real axis.

Returns

[3] The **`cpow`** function returns the complex power function **`xy`**.

7.7.2.19 The `carg` function

Synopsis

[1]

```
#include <complex.h>
double carg(double complex z);
```

Description

[2] The **`carg`** function computes the argument or phase angle of **`z`**, with a branch cut along the negative real axis.

Returns

[3] The **`carg`** function returns the argument or phase angle of **`z`**, in the range **[-π, π]**.

7.7.2.20 The `conj` function

Synopsis

[1]

```
#include <complex.h>
double complex conj(double complex z);
```

Description

[2] The **`conj`** function computes the complex conjugate of **`z`**, by reversing the sign of its imaginary part.

Returns

[3] The **`conj`** function returns the complex conjugate of **`z`**.

7.7.2.21 The `cimag` function

Synopsis

[1]

```
#include <complex.h>
double cimag(double complex z);
```

Description

[2] The **`cimag`** function computes the imaginary part of **`z`**.[142]

Returns

[3] The **`cimag`** function returns the imaginary part of **`z`** (as a real).

7.7.2.22 The `cproj` function

Synopsis

[1]

```
#include <complex.h>
double complex cproj(double complex z);
```

Description

[2] The **`cproj`** function computes a projection of **`z`** onto the Riemann sphere: **`z`** projects to **`z`** except that all complex infinities (even ones with one infinite part and one NaN part) project to positive infinity on the real axis. If **`z`** has an infinite part, then **`cproj(z)`** is equivalent to **`INFINITY + I * copysign(0.0, cimag(z))`**.

142. For a variable **`z`** of complex type, **`z == creal(z) + cimag(z)*I`**.

Returns

[3] The **cproj** function returns a projection of **z** onto the Riemann sphere.

7.7.2.23 The creal function

Synopsis

[1]

```
#include <complex.h>
double creal(double complex z);
```

Description

[2] The **creal** function computes the real part of **z**.

Returns

[3] The **creal** function returns the real part of **z**.

7.8 Nonlocal jumps `<setjmp.h>`

[1] The header `<setjmp.h>` defines the macro `setjmp`, and declares one function and one type, for bypassing the normal function call and return discipline.[143]

[2] The type declared is

```
jmp_buf
```

which is an array type suitable for holding the information needed to restore a calling environment.

[3] It is unspecified whether `setjmp` is a macro or an identifier declared with external linkage. If a macro definition is suppressed in order to access an actual function, or a program defines an external identifier with the name `setjmp`, the behavior is undefined.

7.8.1 Save calling environment

7.8.1.1 The `setjmp` macro

Synopsis

[1]

```
#include <setjmp.h>
int setjmp(jmp_buf env);
```

Description

[2] The `setjmp` macro saves its calling environment in its `jmp_buf` argument for later use by the `longjmp` function.

Returns

[3] If the return is from a direct invocation, the `setjmp` macro returns the value zero. If the return is from a call to the `longjmp` function, the `setjmp` macro returns a nonzero value.

Environmental constraint

[4] An invocation of the `setjmp` macro shall appear only in one of the following contexts:

— the entire controlling expression of a selection or iteration statement;

— one operand of a relational or equality operator with the other operand an integral constant expression, with the resulting expression being the entire controlling

143. These functions are useful for dealing with unusual conditions encountered in a low-level function of a program.

expression of a selection or iteration statement;

— the operand of a unary **!** operator with the resulting expression being the entire controlling expression of a selection or iteration statement; or

— the entire expression of an expression statement (possibly cast to **void**).

7.8.2 Restore calling environment

7.8.2.1 The longjmp function

Synopsis

[1]

```
#include <setjmp.h>
void longjmp(jmp_buf env, int val);
```

Description

[2] The **longjmp** function restores the environment saved by the most recent invocation of the **setjmp** macro in the same invocation of the program, with the corresponding **jmp_buf** argument. If there has been no such invocation, or if the function containing the invocation of the **setjmp** macro has terminated execution[144] in the interim, the behavior is undefined.

[3] All accessible objects have values as of the time **longjmp** was called, except that the values of objects of automatic storage duration that are local to the function containing the invocation of the corresponding **setjmp** macro that do not have volatile-qualified type and have been changed between the **setjmp** invocation and **longjmp** call are indeterminate.

[4] As it bypasses the usual function call and return mechanisms, the **longjmp** function shall execute correctly in contexts of interrupts, signals and any of their associated functions. However, if the **longjmp** function is invoked from a nested signal handler (that is, from a function invoked as a result of a signal raised during the handling of another signal), the behavior is undefined.

Returns

[5] After **longjmp** is completed, program execution continues as if the corresponding invocation of the **setjmp** macro had just returned the value specified by **val**. The **longjmp** function cannot cause the **setjmp** macro to return the value 0; if **val** is 0, the **setjmp** macro returns the value 1.

---

144. For example, by executing a **return** statement or because another **longjmp** call has caused a transfer to a **setjmp** invocation in a function earlier in the set of nested calls.

7.9 Signal handling `<signal.h>`

[1] The header **`<signal.h>`** declares a type and two functions and defines several macros, for handling various *signals* (conditions that may be reported during program execution).

[2] The type defined is

```
sig_atomic_t
```

which is the integral type of an object that can be accessed as an atomic entity, even in the presence of asynchronous interrupts.

[3] The macros defined are

```
SIG_DFL
SIG_ERR
SIG_IGN
```

which expand to constant expressions with distinct values that have type compatible with the second argument to and the return value of the **`signal`** function, and whose value compares unequal to the address of any declarable function; and the following, which expand to positive integral constant expressions with distinct values that are the signal numbers, each corresponding to the specified condition: *

`SIGABRT` abnormal termination, such as is initiated by the **`abort`** function

`SIGFPE` an erroneous arithmetic operation, such as zero divide or an operation resulting in overflow

`SIGILL` detection of an invalid function image, such as an illegal instruction

`SIGINT` receipt of an interactive attention signal

`SIGSEGV` an invalid access to storage

`SIGTERM` a termination request sent to the program

[4] An implementation need not generate any of these signals, except as a result of explicit calls to the **`raise`** function. Additional signals and pointers to undeclarable functions, with macro definitions beginning, respectively, with the letters **`SIG`** and an uppercase letter or with **`SIG_`** and an uppercase letter,[145] may also be specified by the implementation. The complete set of signals, their semantics, and their default handling is implementation-defined; all signal numbers shall be positive.

---

145. See ‘‘future library directions’’ (7.18.5). The names of the signal numbers reflect the following terms (respectively): abort, floating-point exception, illegal instruction, interrupt, segmentation violation, and termination.

7.9.1 Specify signal handling

7.9.1.1 The `signal` function

Synopsis

[1]

```
#include <signal.h>
void (*signal(int sig, void (*func)(int)))(int);
```

Description

[2] The **`signal`** function chooses one of three ways in which receipt of the signal number **`sig`** is to be subsequently handled. If the value of **`func`** is **`SIG_DFL`**, default handling for that signal will occur. If the value of **`func`** is **`SIG_IGN`**, the signal will be ignored. Otherwise, **`func`** shall point to a function to be called when that signal occurs. Such a function is called a *signal handler*.

[3] When a signal occurs, if **`func`** points to a function, first the equivalent of **`signal(sig, SIG_DFL);`** is executed or an implementation-defined blocking of the signal is performed. (If the value of **`sig`** is **`SIGILL,`** whether the reset to **`SIG_DFL`** occurs is implementation-defined.) Next the equivalent of **`(*func)(sig);`** is executed. The function **`func`** may terminate by executing a **`return`** statement or by calling the **`abort`**, **`exit`**, or **`longjmp`** function. If **`func`** executes a **`return`** statement and the value of **`sig`** was **`SIGFPE`** or any other implementation-defined value corresponding to a computational exception, the behavior is undefined. Otherwise, the program will resume execution at the point it was interrupted.

[4] If the signal occurs other than as the result of calling the **`abort`** or **`raise`** function, the behavior is undefined if the signal handler calls any function in the standard library other than the **`signal`** function itself (with a first argument of the signal number corresponding to the signal that caused the invocation of the handler) or refers to any object with static storage duration other than by assigning a value to a static storage duration variable of type **`volatile sig_atomic_t`**. Furthermore, if such a call to the **`signal`** function results in a **`SIG_ERR`** return, the value of **`errno`** is indeterminate.[146]

[5] At program startup, the equivalent of

```
signal(sig, SIG_IGN);
```

may be executed for some signals selected in an implementation-defined manner; the equivalent of

---

146. If any signal is generated by an asynchronous signal handler, the behavior is undefined.

```
signal(sig, SIG_DFL);
```

is executed for all other signals defined by the implementation.

[6] The implementation shall behave as if no library function calls the **`signal`** function.

Returns

[7] If the request can be honored, the **`signal`** function returns the value of **`func`** for the most recent call to **`signal`** for the specified signal **`sig`**. Otherwise, a value of **`SIG_ERR`** is returned and a positive value is stored in **`errno`**.

Forward references: the **`abort`** function (7.12.4.1), the **`exit`** function (7.12.4.3).

7.9.2 Send signal

7.9.2.1 The `raise` function

Synopsis

[1]

```
#include <signal.h>
int raise(int sig);
```

Description

[2] The **`raise`** function sends the signal **`sig`** to the executing program.

Returns

[3] The **`raise`** function returns zero if successful, nonzero if unsuccessful.

7.10 Variable arguments <stdarg.h>

[1] The header **`<stdarg.h>`** declares a type and defines three macros, for advancing through a list of arguments whose number and types are not known to the called function when it is translated.

[2] A function may be called with a variable number of arguments of varying types. As described in 6.7.1, its parameter list contains one or more parameters. The rightmost parameter plays a special role in the access mechanism, and will be designated *parmN* in this description.

[3] The type declared is

```
va_list
```

which is a type suitable for holding information needed by the macros **`va_start`**, **`va_arg`**, and **`va_end`**. If access to the varying arguments is desired, the called function shall declare an object (referred to as **`ap`** in this subclause) having type **`va_list`**. The object **`ap`** may be passed as an argument to another function; if that function invokes the **`va_arg`** macro with parameter **`ap`**, the value of **`ap`** in the calling function is indeterminate and shall be passed to the **`va_end`** macro prior to any further reference to **`ap`**.

7.10.1 Variable argument list access macros

[1] The **`va_start`** and **`va_arg`** macros described in this subclause shall be implemented as macros, not as actual functions. It is unspecified whether **`va_end`** is a macro or an identifier declared with external linkage. If a macro definition is suppressed in order to access an actual function, or a program defines an external identifier with the name **`va_end`**, the behavior is undefined. The **`va_start`** and **`va_end`** macros shall be invoked in corresponding pairs in the function accepting a varying number of arguments, if access to the varying arguments is desired.

7.10.1.1 The va_start macro

Synopsis

[1]

```
#include <stdarg.h>
void va_start(va_list ap, parmN);
```

Description

[2] The **`va_start`** macro shall be invoked before any access to the unnamed arguments.

[3] The **`va_start`** macro initializes **`ap`** for subsequent use by **`va_arg`** and **`va_end`**. **`va_start`** shall not be invoked again for the same **`ap`** without an intervening invocation of **`va_end`** for the same **`ap`**.

[4] The parameter *parmN* is the identifier of the rightmost parameter in the variable parameter list in the function definition (the one just before the **`, ...`**). If the parameter *parmN* is declared with the **register** storage class, with a function or array type, or with a type that is not compatible with the type that results after application of the default argument promotions, the behavior is undefined.

Returns

[5] The **va_start** macro returns no value.

7.10.1.2 The va_arg macro

Synopsis

[1]

```
#include <stdarg.h>
type va_arg(va_list ap, type);
```

Description

[2] The **va_arg** macro expands to an expression that has the type and value of the next argument in the call. The parameter **ap** shall be the same as the **va_list ap** initialized by **va_start**. Each invocation of **va_arg** modifies **ap** so that the values of successive arguments are returned in turn. The parameter *type* is a type name specified such that the type of a pointer to an object that has the specified type can be obtained simply by postfixing a ***** to *type*. If there is no actual next argument, or if *type* is not compatible with the type of the actual next argument (as promoted according to the default argument promotions), the behavior is undefined.

Returns

[3] The first invocation of the **va_arg** macro after that of the **va_start** macro returns the value of the argument after that specified by *parmN*. Successive invocations return the values of the remaining arguments in succession.

7.10.1.3 The va_end macro

Synopsis

[1]

```
#include <stdarg.h>
void va_end(va_list ap);
```

Description

[2] The **va_end** macro facilitates a normal return from the function whose variable argument list was referred to by the expansion of **va_start** that initialized the **va_list ap**. The **va_end** macro may modify **ap** so that it is no longer usable (without an intervening invocation of **va_start**). If there is no corresponding invocation of the **va_start** macro, or if the **va_end** macro is not invoked before the return, the behavior is undefined.

Returns

[3] The **va_end** macro returns no value.

Example

[4] The function **f1** gathers into an array a list of arguments that are pointers to strings (but not more than **MAXARGS** arguments), then passes the array as a single argument to function **f2**. The number of pointers is specified by the first argument to **f1**.

```
#include <stdarg.h>
#define MAXARGS     31

void f1(int n_ptrs, ...)
{
     va_list ap;
     char *array[MAXARGS];
     int ptr_no = 0;

     if (n_ptrs > MAXARGS)
          n_ptrs = MAXARGS;
     va_start(ap, n_ptrs);
     while (ptr_no < n_ptrs)
          array[ptr_no++] = va_arg(ap, char *);
     va_end(ap);
     f2(n_ptrs, array);
}
```

Each call to **f1** shall have visible the definition of the function or a declaration such as

```
void f1(int, ...);
```

7.11 Input/output `<stdio.h>`

7.11.1 Introduction

[1] The header **`<stdio.h>`** declares three types, several macros, and many functions for performing input and output.

[2] The types declared are **`size_t`** (described in 7.1.6);

`FILE`

which is an object type capable of recording all the information needed to control a stream, including its file position indicator, a pointer to its associated buffer (if any), an *error indicator* that records whether a read/write error has occurred, and an *end-of-file indicator* that records whether the end of the file has been reached; and

`fpos_t`

which is an object type capable of recording all the information needed to specify uniquely every position within a file.

[3] The macros are **`NULL`** (described in 7.1.6);

`_IOFBF`
`_IOLBF`
`_IONBF`

which expand to integral constant expressions with distinct values, suitable for use as the third argument to the **`setvbuf`** function;

`BUFSIZ`

which expands to an integral constant expression, which is the size of the buffer used by the **`setbuf`** function;

`EOF`

which expands to a negative integral constant expression that is returned by several functions to indicate *end-of-file*, that is, no more input from a stream;

`FOPEN_MAX`

which expands to an integral constant expression that is the minimum number of files that the implementation guarantees can be open simultaneously;

`FILENAME_MAX`

which expands to an integral constant expression that is the size needed for an array of **`char`** large enough to hold the longest file name string that the implementation guarantees can be opened;[147]

L_tmpnam

which expands to an integral constant expression that is the size needed for an array of **char** large enough to hold a temporary file name string generated by the **tmpnam** function;

SEEK_CUR
SEEK_END
SEEK_SET

which expand to integral constant expressions with distinct values, suitable for use as the third argument to the **fseek** function;

TMP_MAX

which expands to an integral constant expression that is the minimum number of unique file names that shall be generated by the **tmpnam** function;

stderr
stdin
stdout

which are expressions of type ‘‘pointer to **FILE**’’ that point to the **FILE** objects associated, respectively, with the standard error, input, and output streams.

[4] The header **<wchar.h>** declares a number of functions useful for wide-character input and output.

[5] The wide-character input/output functions described in this subclause provide operations analogous to most of those described in subclause 7.11, except that the fundamental units internal to the program are wide characters. The external representation (in the file) is a sequence of ‘‘generalized’’ multibyte characters, as described further in subclause 7.11.3.

[6] The input/output functions are given the following collective terms:

- The *wide-character input functions* — those functions described in this subclause that perform input into wide characters and wide strings: **fgetwc**, **fgetws**, **getwc**, **getwchar**, **fwscanf**, and **wscanf**.
- The *wide-character output functions* — those functions described in this subclause that perform output from wide characters and wide strings: **fputwc**, **fputws**, **putwc**, **putwchar**, **fwprintf**, **wprintf**, **vfwprintf**, and **vwprintf**.

---

147. If the implementation imposes no practical limit on the length of file name strings, the value of **FILENAME_MAX** should instead be the recommended size of an array intended to hold a file name string. Of course, file name string contents are subject to other system-specific constraints; therefore *all* possible strings of length **FILENAME_MAX** cannot be expected to be opened successfully.

- The *wide-character input/output functions* — the union of the **ungetwc** function, the wide-character input functions, and the wide-character output functions.
- The *byte input/output functions* — the **ungetc** function and the input/output functions described in ISO/IEC 9899:1990 subclause 7.11: **fgetc**, **fgets**, **fprintf**, **fputc**, **fputs**, **fread**, **fscanf**, **fwrite**, **getc**, **getchar**, **gets**, **printf**, **putc**, **putchar**, **puts**, **scanf**, **vfprintf**, and **vprintf**.

Forward references: files (7.11.3), the **fseek** function (7.11.9.2), streams (7.11.2), the **tmpnam** function (7.11.4.4).

7.11.2 Streams

[1] Input and output, whether to or from physical devices such as terminals and tape drives, or whether to or from files supported on structured storage devices, are mapped into logical data *streams*, whose properties are more uniform than their various inputs and outputs. Two forms of mapping are supported, for *text streams* and for *binary streams*.[148]

[2] A text stream is an ordered sequence of characters composed into *lines*, each line consisting of zero or more characters plus a terminating new-line character. Whether the last line requires a terminating new-line character is implementation-defined. Characters may have to be added, altered, or deleted on input and output to conform to differing conventions for representing text in the host environment. Thus, there need not be a one-to-one correspondence between the characters in a stream and those in the external representation. Data read in from a text stream will necessarily compare equal to the data that were earlier written out to that stream only if: the data consist only of printable characters and the control characters horizontal tab and new-line; no new-line character is immediately preceded by space characters; and the last character is a new-line character. Whether space characters that are written out immediately before a new-line character appear when read in is implementation-defined.

[3] A binary stream is an ordered sequence of characters that can transparently record internal data. Data read in from a binary stream shall compare equal to the data that were earlier written out to that stream, under the same implementation. Such a stream may, however, have an implementation-defined number of null characters appended to the end of the stream.

[4] Each stream has an *orientation*. After a stream is associated with an external file, but before any operations are performed on it, the stream is without orientation. Once a wide-character input/output function has been applied to a stream without orientation, the stream becomes *wide-oriented*. Similarly, once a byte input/output

148. An implementation need not distinguish between text streams and binary streams. In such an implementation, there need be no new-line characters in a text stream nor any limit to the length of a line.

function has been applied to a stream without orientation, the stream becomes *byte-oriented*. Only a call to the **freopen** function or the **fwide** function can otherwise alter the orientation of a stream. (A successful call to **freopen** removes any orientation.)[149]

[5] Byte input/output functions shall not be applied to a wide-oriented stream; and wide-character input/output functions shall not be applied to a byte-oriented stream. The remaining stream operations do not affect and are not affected by a stream's orientation, except for the following additional restrictions:

- Binary wide-oriented streams have the file-positioning restrictions ascribed to both text and binary streams.
- For wide-oriented streams, after a successful call to a file-positioning function that leaves the file position indicator prior to the end-of-file, a wide-character output function can overwrite a partial multibyte character; any file contents beyond the byte(s) written are henceforth undefined.

[6] Each wide-oriented stream has an associated **mbstate_t** object that stores the current parse state of the stream. A successful call to **fgetpos** stores a representation of the value of this **mbstate_t** object as part of the value of the **fpos_t** object. A later successful call to **fsetpos** using the same stored **fpos_t** value restores the value of the associated **mbstate_t** object as well as the position within the controlled stream.

Environmental limits

[7] An implementation shall support text files with lines containing at least 254 characters, including the terminating new-line character. The value of the macro **BUFSIZ** shall be at least 256.

7.11.3 Files

[1] A stream is associated with an external file (which may be a physical device) by *opening* a file, which may involve *creating* a new file. Creating an existing file causes its former contents to be discarded, if necessary. If a file can support positioning requests (such as a disk file, as opposed to a terminal), then a *file position indicator*[150] associated with the stream is positioned at the start (character number zero) of the file, unless the file is opened with append mode in which case it is implementation-defined whether the file position indicator is initially positioned at the beginning or the end of the file. The file position indicator is maintained by subsequent reads, writes, and positioning requests, to facilitate an orderly progression through the file. All input

149. The three predefined streams **stdin**, **stdout**, and **stderr** are unoriented at program startup.

150. This is described in the Base Document as a *file pointer*. That term is not used in this International Standard to avoid confusion with a pointer to an object that has type **FILE**.

takes place as if characters were read by successive calls to the **fgetc** function; all output takes place as if characters were written by successive calls to the **fputc** function.

[2] Binary files are not truncated, except as defined in 7.11.5.3. Whether a write on a text stream causes the associated file to be truncated beyond that point is implementation-defined.

[3] When a stream is *unbuffered*, characters are intended to appear from the source or at the destination as soon as possible. Otherwise characters may be accumulated and transmitted to or from the host environment as a block. When a stream is *fully buffered*, characters are intended to be transmitted to or from the host environment as a block when a buffer is filled. When a stream is *line buffered*, characters are intended to be transmitted to or from the host environment as a block when a new-line character is encountered. Furthermore, characters are intended to be transmitted as a block to the host environment when a buffer is filled, when input is requested on an unbuffered stream, or when input is requested on a line buffered stream that requires the transmission of characters from the host environment. Support for these characteristics is implementation-defined, and may be affected via the **setbuf** and **setvbuf** functions.

[4] A file may be disassociated from a controlling stream by *closing* the file. Output streams are flushed (any unwritten buffer contents are transmitted to the host environment) before the stream is disassociated from the file. The value of a pointer to a **FILE** object is indeterminate after the associated file is closed (including the standard text streams). Whether a file of zero length (on which no characters have been written by an output stream) actually exists is implementation-defined.

[5] The file may be subsequently reopened, by the same or another program execution, and its contents reclaimed or modified (if it can be repositioned at its start). If the **main** function returns to its original caller, or if the **exit** function is called, all open files are closed (hence all output streams are flushed) before program termination. Other paths to program termination, such as calling the **abort** function, need not close all files properly.

[6] The address of the **FILE** object used to control a stream may be significant; a copy of a **FILE** object may not necessarily serve in place of the original.

[7] At program startup, three text streams are predefined and need not be opened explicitly — *standard input* (for reading conventional input), *standard output* (for writing conventional output), and *standard error* (for writing diagnostic output). When opened, the standard error stream is not fully buffered; the standard input and standard output streams are fully buffered if and only if the stream can be determined not to refer to an interactive device.

[8] Functions that open additional (nontemporary) files require a *file name*, which is a string. The rules for composing valid file names are implementation-defined. Whether the same file can be simultaneously open multiple times is also implementation-defined.

[9] Although both text and binary wide-oriented streams are conceptually sequences of wide characters, the external file associated with a wide-oriented stream is a sequence of multibyte characters, generalized as follows:

- Multibyte encodings within files may contain embedded null bytes (unlike multibyte encodings valid for use internal to the program).
- A file need not begin nor end in the initial shift state.[151]

[10] Moreover, the encodings used for multibyte characters may differ among files. Both the nature and choice of such encodings are implementation defined.

[11] The wide-character input functions read multibyte characters from the stream and convert them to wide characters as if they were read by successive calls to the **`fgetwc`** function. Each conversion occurs as if by a call to the **`mbrtowc`** function, with the conversion state described by the stream's own **`mbstate_t`** object.

[12] The wide-character output functions convert wide characters to multibyte characters and write them to the stream as if they were written by successive calls to the **`fputwc`** function. Each conversion occurs as if by a call to the **`wcrtomb`** function, with the conversion state described by the stream's own **`mbstate_t`** object.

[13] An *encoding error* occurs if the character sequence presented to the underlying **`mbrtowc`** function does not form a valid (generalized) multibyte character, or if the code value passed to the underlying **`wcrtomb`** does not correspond to a valid (generalized) multibyte character. The wide-character input/output functions and the byte input/output functions store the value of the macro **`EILSEQ`** in **`errno`** if and only if an encoding error occurs.

Environmental limits

[14] The value of **`FOPEN_MAX`** shall be at least eight, including the three standard text streams.

Forward references: the **`exit`** function (7.12.4.3), the **`fgetc`** function (7.11.7.1), the **`fopen`** function (7.11.5.3), the **`fputc`** function (7.11.7.3), the **`setbuf`** function (7.11.5.5), the **`setvbuf`** function (7.11.5.6), the **`fgetwc`** function (7.17.3.1), the **`fputwc`** function (7.17.3.3), conversion state (7.17.6), the **`mbrtowc`** function (7.17.6.3.2), the **`wcrtomb`** function (7.17.6.3.3).

151. Setting the file position indicator to end-of-file, as with **`fseek(file, 0, SEEK_END)`**, has undefined behavior for a binary stream (because of possible trailing null characters) or for any stream with state-dependent encoding that does not assuredly end in the initial shift state.

7.11.4 Operations on files

7.11.4.1 The `remove` function

Synopsis

[1]

```
#include <stdio.h>
int remove(const char *filename);
```

Description

[2] The **`remove`** function causes the file whose name is the string pointed to by **`filename`** to be no longer accessible by that name. A subsequent attempt to open that file using that name will fail, unless it is created anew. If the file is open, the behavior of the **`remove`** function is implementation-defined.

Returns

[3] The **`remove`** function returns zero if the operation succeeds, nonzero if it fails.

7.11.4.2 The `rename` function

Synopsis

[1]

```
#include <stdio.h>
int rename(const char *old, const char *new);
```

Description

[2] The **`rename`** function causes the file whose name is the string pointed to by **`old`** to be henceforth known by the name given by the string pointed to by **`new`**. The file named **`old`** is no longer accessible by that name. If a file named by the string pointed to by **`new`** exists prior to the call to the **`rename`** function, the behavior is implementation-defined.

Returns

[3] The **`rename`** function returns zero if the operation succeeds, nonzero if it fails,[152] in which case if the file existed previously it is still known by its original name.

152. Among the reasons the implementation may cause the **`rename`** function to fail are that the file is open or that it is necessary to copy its contents to effectuate its renaming.

7.11.4.3 The `tmpfile` function

Synopsis

[1]

```
#include <stdio.h>
FILE *tmpfile(void);
```

Description

[2] The **tmpfile** function creates a temporary binary file that will automatically be removed when it is closed or at program termination. If the program terminates abnormally, whether an open temporary file is removed is implementation-defined. The file is opened for update with **"wb+"** mode.

Returns

[3] The **tmpfile** function returns a pointer to the stream of the file that it created. If the file cannot be created, the **tmpfile** function returns a null pointer.

Forward references: the **fopen** function (7.11.5.3).

7.11.4.4 The `tmpnam` function

Synopsis

[1]

```
#include <stdio.h>
char *tmpnam(char *s);
```

Description

[2] The **tmpnam** function generates a string that is a valid file name and that is not the same as the name of an existing file.[153]

[3] The **tmpnam** function generates a different string each time it is called, up to **TMP_MAX** times. If it is called more than **TMP_MAX** times, the behavior is implementation-defined.

[4] The implementation shall behave as if no library function calls the **tmpnam** function.

Returns

[5] If the argument is a null pointer, the **tmpnam** function leaves its result in an

---

153. Files created using strings generated by the **tmpnam** function are temporary only in the sense that their names should not collide with those generated by conventional naming rules for the implementation. It is still necessary to use the **remove** function to remove such files when their use is ended, and before program termination.

internal static object and returns a pointer to that object. Subsequent calls to the **tmpnam** function may modify the same object. If the argument is not a null pointer, it is assumed to point to an array of at least **L_tmpnam** **char**s; the **tmpnam** function writes its result in that array and returns the argument as its value.

Environmental limits

[6] The value of the macro **TMP_MAX** shall be at least 25.

7.11.5 File access functions

7.11.5.1 The fclose function

Synopsis

[1]

```
#include <stdio.h>
int fclose(FILE *stream);
```

Description

[2] The **fclose** function causes the stream pointed to by **stream** to be flushed and the associated file to be closed. Any unwritten buffered data for the stream are delivered to the host environment to be written to the file; any unread buffered data are discarded. The stream is disassociated from the file. If the associated buffer was automatically allocated, it is deallocated.

Returns

[3] The **fclose** function returns zero if the stream was successfully closed, or **EOF** if any errors were detected.

7.11.5.2 The fflush function

Synopsis

[1]

```
#include <stdio.h>
int fflush(FILE *stream);
```

Description

[2] If **stream** points to an output stream or an update stream in which the most recent operation was not input, the **fflush** function causes any unwritten data for that stream to be delivered to the host environment to be written to the file; otherwise, the behavior is undefined.

[3] If **stream** is a null pointer, the **fflush** function performs this flushing action on all streams for which the behavior is defined above.

Returns

[4] The **fflush** function returns **EOF** if a write error occurs, otherwise zero.

Forward references: the **fopen** function (7.11.5.3), the **ungetc** function (7.11.7.11).

7.11.5.3 The fopen function

Synopsis

[1]

```
#include <stdio.h>
FILE *fopen(const char *filename, const char *mode);
```

Description

[2] The **fopen** function opens the file whose name is the string pointed to by **filename**, and associates a stream with it.

[3] The argument **mode** points to a string beginning with one of the following sequences:[154]

r	open text file for reading
w	truncate to zero length or create text file for writing
a	append; open or create text file for writing at end-of-file
rb	open binary file for reading
wb	truncate to zero length or create binary file for writing
ab	append; open or create binary file for writing at end-of-file
r+	open text file for update (reading and writing)
w+	truncate to zero length or create text file for update
a+	append; open or create text file for update, writing at end-of-file
r+b *or* **rb+**	open binary file for update (reading and writing)
w+b *or* **wb+**	truncate to zero length or create binary file for update
a+b *or* **ab+**	append; open or create binary file for update, writing at end-of-file

[4] Opening a file with read mode (**'r'** as the first character in the **mode** argument) fails if the file does not exist or cannot be read.

[5] Opening a file with append mode (**'a'** as the first character in the **mode** argument) causes all subsequent writes to the file to be forced to the then current end-of-file, regardless of intervening calls to the **fseek** function. In some implementations, opening a binary file with append mode (**'b'** as the second or third character in the above list of **mode** argument values) may initially position the file position indicator for the stream beyond the last data written, because of null character padding.

[6] When a file is opened with update mode (**'+'** as the second or third character in the above list of **mode** argument values), both input and output may be performed on the associated stream. However, output may not be directly followed by input without

154. Additional characters may follow these sequences.

an intervening call to the **fflush** function or to a file positioning function (**fseek**, **fsetpos**, or **rewind**), and input may not be directly followed by output without an intervening call to a file positioning function, unless the input operation encounters end-of-file. Opening (or creating) a text file with update mode may instead open (or create) a binary stream in some implementations.

[7] When opened, a stream is fully buffered if and only if it can be determined not to refer to an interactive device. The error and end-of-file indicators for the stream are cleared.

Returns

[8] The **fopen** function returns a pointer to the object controlling the stream. If the open operation fails, **fopen** returns a null pointer.

Forward references: file positioning functions (7.11.9).

7.11.5.4 The freopen function

Synopsis

[1]

```
#include <stdio.h>
FILE *freopen(const char * restrict filename,
     const char * restrict mode,
     FILE * restrict stream);
```

Description

[2] The **freopen** function opens the file whose name is the string pointed to by **filename** and associates the stream pointed to by **stream** with it. The **mode** argument is used just as in the **fopen** function.[155]

[3] The **freopen** function first attempts to close any file that is associated with the specified stream. Failure to close the file successfully is ignored. The error and end-of-file indicators for the stream are cleared.

Returns

[4] The **freopen** function returns a null pointer if the open operation fails. Otherwise, **freopen** returns the value of **stream**.

155. The primary use of the **freopen** function is to change the file associated with a standard text stream (**stderr**, **stdin**, or **stdout**), as those identifiers need not be modifiable lvalues to which the value returned by the **fopen** function may be assigned.

7.11.5.5 The `setbuf` function

Synopsis

[1]

```
#include <stdio.h>
void setbuf(FILE * restrict stream,
     char * restrict buf);
```

Description

[2] Except that it returns no value, the **setbuf** function is equivalent to the **setvbuf** function invoked with the values **_IOFBF** for **mode** and **BUFSIZ** for **size**, or (if **buf** is a null pointer), with the value **_IONBF** for **mode**.

Returns

[3] The **setbuf** function returns no value.

Forward references: the **setvbuf** function (7.11.5.6).

7.11.5.6 The `setvbuf` function

Synopsis

[1]

```
#include <stdio.h>
int setvbuf(FILE * restrict stream,
     char * restrict buf,
     int mode, size_t size);
```

Description

[2] The **setvbuf** function may be used only after the stream pointed to by **stream** has been associated with an open file and before any other operation is performed on the stream. The argument **mode** determines how **stream** will be buffered, as follows: **_IOFBF** causes input/output to be fully buffered; **_IOLBF** causes input/output to be line buffered; **_IONBF** causes input/output to be unbuffered. If **buf** is not a null pointer, the array it points to may be used instead of a buffer allocated by the **setvbuf** function.[156] The argument **size** specifies the size of the array. The contents of the array at any time are indeterminate.

Returns

[3] The **setvbuf** function returns zero on success, or nonzero if an invalid value is

156. The buffer must have a lifetime at least as great as the open stream, so the stream should be closed before a buffer that has automatic storage duration is deallocated upon block exit.

given for **mode** or if the request cannot be honored.

7.11.6 Formatted input/output functions

7.11.6.1 The fprintf function

Synopsis

[1]

```
#include <stdio.h>
int fprintf(FILE * restrict stream,
     const char * restrict format, ...);
```

Description

[2] The **fprintf** function writes output to the stream pointed to by **stream**, under control of the string pointed to by **format** that specifies how subsequent arguments are converted for output. If there are insufficient arguments for the format, the behavior is undefined. If the format is exhausted while arguments remain, the excess arguments are evaluated (as always) but are otherwise ignored. The **fprintf** function returns when the end of the format string is encountered.

[3] The format shall be a multibyte character sequence, beginning and ending in its initial shift state. The format is composed of zero or more directives: ordinary multibyte characters (not **%**), which are copied unchanged to the output stream; and conversion specifications, each of which results in fetching zero or more subsequent arguments. Each conversion specification is introduced by the character **%**. After the **%**, the following appear in sequence:

— Zero or more *flags* (in any order) that modify the meaning of the conversion specification.

— An optional minimum *field width*. If the converted value has fewer characters than the field width, it will be padded with spaces (by default) on the left (or right, if the left adjustment flag, described later, has been given) to the field width. The field width takes the form of an asterisk ***** (described later) or a decimal integer.[157]

— An optional *precision* that gives the minimum number of digits to appear for the **d**, **i**, **o**, **u**, **x**, and **X** conversions, the number of digits to appear after the decimal-point character for **e**, **E**, and **f** conversions, the maximum number of significant digits for the **g** and **G** conversions, or the maximum number of characters to be written from a string in **s** conversion. The precision takes the form of a period (**.**) followed either by an asterisk ***** (described later) or by an optional decimal integer; if only the period is specified, the precision is taken as zero. If a precision appears with any other conversion specifier, the behavior is undefined.

157. Note that **0** is taken as a flag, not as the beginning of a field width.

— An optional **h** specifying that a following **d**, **i**, **o**, **u**, **x**, or **X** conversion specifier applies to a **short int** or **unsigned short int** argument (the argument will have been promoted according to the integral promotions, and its value shall be converted to **short int** or **unsigned short int** before printing); an optional **h** specifying that a following **n** conversion specifier applies to a pointer to a **short int** argument; an optional **l** (ell) specifying that a following **d**, **i**, **o**, **u**, **x**, or **X** conversion specifier applies to a **long int** or **unsigned long int** argument; an optional **ll** (ell-ell) specifying that a following **d**, **i**, **o**, **u**, **x**, or **X** conversion specifier applies to a **long long int** or **unsigned long long int** argument; an optional **l** specifying that a following **n** conversion specifier applies to a pointer to a **long int** argument; an optional **ll** specifying that a following **n** conversion specifier applies to a pointer to a **long long int** argument; an optional **l** specifying that a following **c** conversion specifier applies to a **wint_t** argument; an optional **l** specifying that a following **s** conversion specifier applies to a pointer to a **wchar_t** argument; or an optional **L** specifying that a following **e**, **E**, **f**, **g**, or **G** conversion specifier applies to a **long double** argument. If an **h**, **l**, **ll**, or **L** appears with any other conversion specifier, the behavior is undefined.

— A character that specifies the type of conversion to be applied.

[4] As noted above, a field width, or precision, or both, may be indicated by an asterisk. In this case, an **int** argument supplies the field width or precision. The arguments specifying field width, or precision, or both, shall appear (in that order) before the argument (if any) to be converted. A negative field width argument is taken as a **-** flag followed by a positive field width. A negative precision argument is taken as if the precision were omitted.

[5] The flag characters and their meanings are

- The result of the conversion will be left-justified within the field. (It will be right-justified if this flag is not specified.)

+ The result of a signed conversion will always begin with a plus or minus sign. (It will begin with a sign only when a negative value is converted if this flag is not specified.)

space If the first character of a signed conversion is not a sign, or if a signed conversion results in no characters, a space will be prefixed to the result. If the *space* and **+** flags both appear, the *space* flag will be ignored.

The result is to be converted to an ‘‘alternate form.’’ For **o** conversion, it increases the precision, if and only if necessary, to force the first digit of the result to be a zero. * For **x** (or **X**) conversion, a nonzero result will have **0x** (or **0X**) prefixed to it. For **a**, **A**, **e**, **E**, **f**, **g**, and **G** conversions, the result will always contain a decimal-point character, even if no digits follow it. (Normally, a decimal-point character appears in the result of these conversions only if a digit follows it.) For **g** and **G** conversions, trailing zeros will *not* be removed from the result. For other conversions, the behavior is undefined.

`0` For **`d`**, **`i`**, **`o`**, **`u`**, **`x`**, **`X`**, **`a`**, **`A`**, **`e`**, **`E`**, **`f`**, **`g`**, and **`G`** conversions, leading zeros (following any indication of sign or base) are used to pad to the field width; no space padding is performed. If the **`0`** and **`-`** flags both appear, the **`0`** flag will be ignored. For **`d`**, **`i`**, **`o`**, **`u`**, **`x`**, and **`X`** conversions, if a precision is specified, the **`0`** flag will be ignored. For other conversions, the behavior is undefined. |

[6] The conversion specifiers and their meanings are *

`d,i` The **`int`** argument is converted to signed decimal in the style *[−]dddd*. The precision specifies the minimum number of digits to appear; if the value being converted can be represented in fewer digits, it will be expanded with leading zeros. The default precision is 1. The result of converting a zero value with a precision of zero is no characters.

`o,u,x,X` The **`unsigned int`** argument is converted to unsigned octal (**`o`**), unsigned decimal (**`u`**), or unsigned hexadecimal notation (**`x`** or **`X`**) in the style *dddd*; the letters **`abcdef`** are used for **`x`** conversion and the letters **`ABCDEF`** for **`X`** conversion. The precision specifies the minimum number of digits to appear; if the value being converted can be represented in fewer digits, it will be expanded with leading zeros. The default precision is 1. The result of converting a zero value with a precision of zero is no characters.

`f` The **`double`** argument is converted to decimal notation in the style *[−]ddd.ddd*, where the number of digits after the decimal-point character is equal to the precision specification. If the precision is missing, it is taken as 6; if the precision is zero and the **`#`** flag is not specified, no decimal-point character appears. If a decimal-point character appears, at least one digit appears before it. The value is rounded to the appropriate number of digits.

`e,E` The **`double`** argument is converted in the style *[−]d.ddd*`e`*±dd*, where there is one digit before the decimal-point character (which is nonzero if the argument is nonzero) and the number of digits after it is equal to the precision; if the precision is missing, it is taken as 6; if the precision is zero and the **`#`** flag is not specified, no decimal-point character appears. The value is rounded to the appropriate number of digits. The **`E`** conversion specifier will produce a number with **`E`** instead of **`e`** introducing the exponent. The exponent always contains at least two digits. If the value is zero, the exponent is zero.

`g,G` The **`double`** argument is converted in style **`f`** or **`e`** (or in style **`E`** in the case of a **`G`** conversion specifier), with the precision specifying the number of significant digits. If the precision is zero, it is taken as 1. The style used depends on the value converted; style **`e`** (or **`E`**) will be used only if the exponent resulting from such a conversion is less than −4 or greater than or equal to the precision. Trailing zeros are removed from the fractional portion of the result; a decimal-point character appears only if it is followed by a digit.

a,A The double argument is converted in the style *[−]0xh.hhhhp***p**±*d*. The number of hexadecimal digits h after the decimal-point character is equal to the precision; if the precision is missing and **FLT_RADIX** is a power of 2, then the precision is sufficient for an exact representation of the value; if the precision is missing and **FLT_RADIX** is not a power of 2, then the precision is sufficient to distinguish[158] values of type double, except that trailing zeros may be omitted. The hexadecimal digit to the left of the decimal-point character is nonzero for normalized floating-point numbers and is otherwise unspecified; if the precision is zero and the **#** flag is not specified, no decimal-point character appears. The lettersr **abcdef** are used for a conversion and the letters **ABCDEF** for **A** conversion. The a conversion specifier will produce a number with **x** and **p** and the **A** conversion specifier will produce a number with **X** and **P**. The exponent always contains at least one digit, and only as many more digits as necessary to represent the decimal exponent of 2. If the value is zero, the exponent is zero.

c If no **l** qualifier is present, the **int** argument is converted to an **unsigned char**, and the resulting character is written. Otherwise, the **wint_t** argument is converted as if by an **ls** conversion specification with no precision and an argument that points to a two-element array of **wchar_t**, the first element containing the **wint_t** argument to the **lc** conversion specification and the second a null wide character.

s If no **l** qualifier is present, the argument shall be a pointer to an array of character type.[159] Characters from the array are written up to (but not including) a terminating null character. If the precision is specified, no more than that many characters are written. If the precision is not specified or is greater than the size of the array, the array shall contain a null character.

If an **l** qualifier is present, the argument shall be a pointer to an array of **wchar_t** type. Wide characters from the array are converted to multibyte characters (each as if by a call to the **wcrtomb** function, with the conversion state described by an **mbstate_t** object initialized to zero

---

158. The precision p is sufficient to distinguish values of the source type if [*FF* missing text here] where *b* is **FLT_RADIX** and *n* is the number of base-b digits in the significand of the source type. A smaller *p* might suffice depending on the implementation's scheme for determining the digit to the left of the decimal-point character.

[*FF* Where does this paragraph go?] Binary implementations can choose the hexadecimal digit to the left of the decimal-point character so that subsequent digits align to nibble (4-bit) boundaries.

159. No special provisions are made for multibyte characters.

before the first wide character is converted) up to and including a terminating null wide character. The resulting multibyte characters are written up to (but not including) the terminating null character (byte). If no precision is specified, the array shall contain a null wide character. If a precision is specified, no more than that many characters (bytes) are written (including shift sequences, if any), and the array shall contain a null wide character if, to equal the multibyte character sequence length given by the precision, the function would need to access a wide character one past the end of the array. In no case is a partial multibyte character written.[160]

`p` The argument shall be a pointer to **`void`**. The value of the pointer is converted to a sequence of printable characters, in an implementation-defined manner.

`n` The argument shall be a pointer to an integer into which is *written* the number of characters written to the output stream so far by this call to **`fprintf`**. No argument is converted.

`%` A **`%`** is written. No argument is converted. The complete conversion specification shall be **`%%`**.

[7] If a conversion specification is invalid, the behavior is undefined.[161]

[8] If any argument is, or points to, a union or an aggregate (except for an array of character type using **`%s`** conversion, or a pointer using **`%p`** conversion), the behavior is undefined.

[9] In no case does a nonexistent or small field width cause truncation of a field; if the result of a conversion is wider than the field width, the field is expanded to contain the conversion result.

[10] For **`a`** and **`A`** conversions, if **`FLT_RADIX`** is a power of 2, the value is correctly rounded to a hexadecimal floating number with the given precision.

Recommended practice

[11] If **`FLT_RADIX`** is not a power of 2, the result is one of the two adjacent numbers in hexadecimal floating style with the given precision, with the extra stipulation that the error have a correct sign for the current rounding direction.

Returns

[12] The **`fprintf`** function returns the number of characters transmitted, or a negative value if an output error occurred.

---

160. Redundant shift sequences may result if multibyte characters have a state-dependent encoding.

161. See ‘‘future library directions’’ (7.18.6).

Environmental limit

[13] The minimum value for the maximum number of characters produced by any single conversion shall be 509.

Example

[14] To print a date and time in the form ‘‘Sunday, July 3, 10:02’’ followed by π to five decimal places:

```
#include <math.h>
#include <stdio.h>
/*...*/
char *weekday, *month;    /* pointers to strings */
int day, hour, min;
fprintf(stdout, "%s, %s %d, %.2d:%.2d\n",
     weekday, month, day, hour, min);
fprintf(stdout, "pi = %.5f\n", 4 * atan(1.0));
```

[15] In this example, multibyte characters do not have a state-dependent encoding, and the multibyte members of the extended character set each consist of two bytes, the first of which is denoted here by a **`$0`** and the second by an uppercase letter.

[16] Given the following wide string with length seven,

```
static wchar_t wstr[] = L"$0X$0Yabc$0Z$0W";
```

[17] the seven calls

```
fprintf(stdout, "|1234567890123|\n");
fprintf(stdout, "|%13ls|\n", wstr);
fprintf(stdout, "|%-13.9ls|\n", wstr);
fprintf(stdout, "|%13.10ls|\n", wstr);
fprintf(stdout, "|%13.1ls|\n", wstr);
fprintf(stdout, "|%13.15ls|\n", &wstr[2]);
fprintf(stdout, "|%13lc|\n", wstr[5]);
```

[18] will print the following seven lines:

```
|1234567890123|
|  $0X$0Yabc$0Z$0W|
|$0X$0Yabc$0Z    |
|    $0X$0Yabc$0Z|
|  $0X$0Yabc$0Z$0W|
|      abc$0Z$0W|
|           $0Z|
```

[19]

Forward references: conversion state (7.17.6), the **`wcrtomb`** function (7.17.6.3.3).

7.11.6.2 The `fscanf` function

Synopsis

[1]

```
#include <stdio.h>
int fscanf(FILE * restrict stream,
     const char * restrict format, ...);
```

Description

[2] The **fscanf** function reads input from the stream pointed to by **stream**, under control of the string pointed to by **format** that specifies the admissible input sequences and how they are to be converted for assignment, using subsequent arguments as pointers to the objects to receive the converted input. If there are insufficient arguments for the format, the behavior is undefined. If the format is exhausted while arguments remain, the excess arguments are evaluated (as always) but are otherwise ignored.

[3] The format shall be a multibyte character sequence, beginning and ending in its initial shift state. The format is composed of zero or more directives: one or more white-space characters; an ordinary multibyte character (neither **%** nor a white-space character); or a conversion specification. Each conversion specification is introduced by the character **%**. After the **%**, the following appear in sequence:

— An optional assignment-suppressing character *****.

— An optional nonzero decimal integer that specifies the maximum field width.

— An optional **h**, **l** (ell), or **ll** (ell-ell), or **L** indicating the size of the receiving object. The conversion specifiers **d**, **i**, and **n** shall be preceded by **h** if the corresponding argument is a pointer to **short int** rather than a pointer to **int**, by **l** if it is a pointer to **long**, or by **ll** if it is a pointer to **long long int**. Similarly, the conversion specifiers **o**, **u**, and **x** shall be preceded by **h** if the corresponding argument is a pointer to **unsigned short int** rather than a pointer to **unsigned int**, by **l** if it is a pointer to **unsigned long int**, or by **ll** if it is a pointer to **unsigned long long int**. Finally, the conversion specifiers **e**, **f**, and **g** shall be preceded by **l** if the corresponding argument is a pointer to **double** rather than a pointer to **float**, or by **L** if it is a pointer to **long double**. The conversion specifiers **c**, **s**, and **[** shall be preceded by **l** if the corresponding argument is a pointer to **wchar_t** rather than a pointer to a character type. If an **h**, **l**, or **L** appears with any other conversion specifier, the behavior is undefined.

— A character that specifies the type of conversion to be applied. The valid conversion specifiers are described below.

[4] The **fscanf** function executes each directive of the format in turn. If a directive fails, as detailed below, the **fscanf** function returns. Failures are described as input failures (due to the unavailability of input characters), or matching failures (due to inappropriate input).

[5] A directive composed of white-space character(s) is executed by reading input up to the first non-white-space character (which remains unread), or until no more characters can be read.

[6] A directive that is an ordinary multibyte character is executed by reading the next characters of the stream. If one of the characters differs from one comprising the directive, the directive fails, and the differing and subsequent characters remain unread.

[7] A directive that is a conversion specification defines a set of matching input sequences, as described below for each specifier. A conversion specification is executed in the following steps:

[8] Input white-space characters (as specified by the **`isspace`** function) are skipped, unless the specification includes a **`[`**, **`c`**, or **`n`** specifier.[162]

[9] An input item is read from the stream, unless the specification includes an **`n`** specifier. An input item is defined as the longest sequence of input characters which does not exceed any specified field width and which is, or is a prefix of, a matching input sequence. The first character, if any, after the input item remains unread. If the length of the input item is zero, the execution of the directive fails; this condition is a matching failure unless end-of-file, an encoding error, or a read error prevented input from the stream, in which case it is an input failure. *

[10] Except in the case of a **`%`** specifier, the input item (or, in the case of a **`%n`** directive, the count of input characters) is converted to a type appropriate to the conversion specifier. If the input item is not a matching sequence, the execution of the directive fails: this condition is a matching failure. Unless assignment suppression was indicated by a **`*`**, the result of the conversion is placed in the object pointed to by the first argument following the **`format`** argument that has not already received a conversion result. If this object does not have an appropriate type, or if the result of the conversion cannot be represented in the space provided, the behavior is undefined.

[11] The following conversion specifiers are valid:

[12]

`d` Matches an optionally signed decimal integer, whose format is the same as expected for the subject sequence of the **`strtol`** function with the value 10 for the **`base`** argument. The corresponding argument shall be a pointer to integer.

162. These white-space characters are not counted against a specified field width.

i Matches an optionally signed integer, whose format is the same as expected for the subject sequence of the **strtol** function with the value 0 for the **base** argument. The corresponding argument shall be a pointer to integer.

o Matches an optionally signed octal integer, whose format is the same as expected for the subject sequence of the **strtoul** function with the value 8 for the **base** argument. The corresponding argument shall be a pointer to unsigned integer.

u Matches an optionally signed decimal integer, whose format is the same as expected for the subject sequence of the **strtoul** function with the value 10 for the **base** argument. The corresponding argument shall be a pointer to unsigned integer.

x Matches an optionally signed hexadecimal integer, whose format is the same as expected for the subject sequence of the **strtoul** function with the value 16 for the **base** argument. The corresponding argument shall be a pointer to unsigned integer.

e,f,g Matches an optionally signed floating-point constant, whose format is the same as expected for the subject string of the **strtod** function. The corresponding argument shall be a pointer to floating.

s Matches a sequence of non-white-space characters.[163] If no **l** qualifier is present, the corresponding argument shall be a pointer to a character array large enough to accept the sequence and a terminating null character, which will be added automatically.

If an **l** qualifier is present, the input shall be a sequence of multibyte characters that begins in the initial shift state. Each multibyte character is converted to a wide character as if by a call to the **mbrtowc** function, with the conversion state described by an **mbstate_t** object initialized to zero before the first multibyte character is converted. The corresponding argument shall be a pointer to an array of **wchar_t** large enough to accept the sequence and the terminating null wide character, which will be added automatically.

[Matches a nonempty sequence of characters from a set of expected characters (the *scanset*). If no **l** qualifier is present, the corresponding argument shall be a pointer to a character array large enough to accept the sequence and a terminating null character, which will be added automatically.

163. No special provisions are made for multibyte characters in the matching rules used by any of the conversion specifiers **s**, **[**, **c** — the extent of the input field is still determined on a byte-by-byte basis. The resulting field must nevertheless be a sequence of multibyte characters that begins in the initial shift state.

If an **l** qualifier is present, the input shall be a sequence of multibyte characters that begins in the initial shift state. Each multibyte character is converted to a wide character as if by a call to the **mbrtowc** function, with the conversion state described by an **mbstate_t** object initialized to zero before the first multibyte character is converted. The corresponding argument shall be a pointer to an array of **wchar_t** large enough to accept the sequence and the terminating null wide character, which will be added automatically. The conversion specifier includes all subsequent characters in the **format** string, up to and including the matching right bracket (**]**). The characters between the brackets (the *scanlist*) comprise the scanset, unless the character after the left bracket is a circumflex (**^**), in which case the scanset contains all characters that do not appear in the scanlist between the circumflex and the right bracket. If the conversion specifier begins with **[]** or **[^]**, the right bracket character is in the scanlist and the next right bracket character is the matching right bracket that ends the specification; otherwise the first right bracket character is the one that ends the specification. If a **-** character is in the scanlist and is not the first, nor the second where the first character is a **^**, nor the last character, the behavior is implementation-defined.

c Matches a sequence of characters of the number specified by the field width (1 if no field width is present in the directive). If no **l** qualifier is present, the corresponding argument shall be a pointer to a character array large enough to accept the sequence. No null character is added. |

If an **l** qualifier is present, the input shall be a sequence of multibyte characters that begins in the initial shift state. Each multibyte character in the sequence is converted to a wide character as if by a call to the **mbrtowc** function, with the conversion state described by an **mbstate_t** object initialized to zero before the first multibyte character is converted. The corresponding argument shall be a pointer to the initial element of an array of **wchar_t** large enough to accept the resulting sequence of wide characters. No null wide character is added.

p Matches an implementation-defined set of sequences, which should be the same as the set of sequences that may be produced by the **%p** conversion of the **fprintf** function. The corresponding argument shall be a pointer to a pointer to **void**. The interpretation of the input item is implementation-defined. If the input item is a value converted earlier during the same program execution, the pointer that results shall compare equal to that value; otherwise the behavior of the **%p** conversion is undefined.

n No input is consumed. The corresponding argument shall be a pointer to integer into which is to be written the number of characters read from the input stream so far by this call to the **fscanf** function. Execution of a **%n** directive does not increment the assignment count returned at the completion of execution of the **fscanf** function. No argument is converted, but one is * consumed. If the conversion specification with this conversion specifier is not one of **`%n`**, **`%ln`**, **`%lln`**, or **`%hn`**, the behavior is undefined.

`%` Matches a single **`%`**; no conversion or assignment occurs. The complete conversion specification shall be **`%%`**.

[13] If a conversion specification is invalid, the behavior is undefined.[164]

[14] The conversion specifiers **`E`**, **`G`**, and **`X`** are also valid and behave the same as, respectively, **`e`**, **`g`**, and **`x`**.

[15] If end-of-file is encountered during input, conversion is terminated. If end-of-file occurs before any characters matching the current directive have been read (other than leading white space, where permitted), execution of the current directive terminates with an input failure; otherwise, unless execution of the current directive is terminated with a matching failure, execution of the following directive (if any) is terminated with an input failure.

[16] Trailing white space (including new-line characters) is left unread unless matched by a directive. The success of literal matches and suppressed assignments is not directly determinable other than via the **`%n`** directive.

[17] If conversion terminates on a conflicting input character, the offending input character is left unread in the input stream.[165]

Returns

[18] The **`fscanf`** function returns the value of the macro **`EOF`** if an input failure occurs before any conversion. Otherwise, the **`fscanf`** function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early matching failure.

Examples

1. The call:

```
#include <stdio.h>
/*...*/
int n, i; float x; char name[50];
n = fscanf(stdin, "%d%f%s", &i, &x, name);
```

with the input line:

```
25 54.32E-1 thompson
```

will assign to *n* the value **`3`**, to *i* the value **`25`**, to *x* the value **`5.432`**, and *name*

---

164. See ‘‘future library directions’’ (7.18.6).

165. **`fscanf`** pushes back at most one input character onto the input stream. Therefore, some sequences that are acceptable to **`strtod`**, **`strtol`**, or **`strtoul`** are unacceptable to **`fscanf`**.

will contain **thompson\0**.

2. The call:

```
#include <stdio.h>
/*...*/
int i; float x; char name[50];
fscanf(stdin, "%2d%f%*d %[0123456789]", &i, &x, name);
```

with input:

```
56789 0123 56a72
```

will assign to *i* the value **56** and to *x* the value **7.10.0**, will skip **0123**, and *name* will contain **56\0**. The next character read from the input stream will be **a**.

3. To accept repeatedly from **stdin** a quantity, a unit of measure and an item name:

```
#include <stdio.h>
/*...*/
int count; float quant; char units[21], item[21];
while (!feof(stdin) && !ferror(stdin)) {
     count = fscanf(stdin, "%f%20s of %20s",
          &quant, units, item);
     fscanf(stdin,"%*[^\n]");
}
```

If the **stdin** stream contains the following lines:

```
2 quarts of oil
-12.8degrees Celsius
lots of luck
10.0LBS     of
dirt
100ergs of energy
```

the execution of the above example will be analogous to the following assignments:

```
quant = 2; strcpy(units, "quarts"); strcpy(item, "oil");
count = 3;
quant = -12.8; strcpy(units, "degrees");
count = 2; /* "C" fails to match "o" */
count = 0; /* "l" fails to match "%f" */
quant = 10.0; strcpy(units, "LBS"); strcpy(item, "dirt");
count = 3;
count = 0; /* "100e" fails to match "%f" */
count = EOF;
```

4. In: *

```
#include <stdio.h>
/* ... */
int d1, d2, n1, n2, i;
i = sscanf("123", "%d%n%n%d", &d1, &n1, &n2, &d2);
```

the value 123 is assigned to **d1** and the value 3 to **n1**. Because **%n** can never get an input failure the value of 3 is also assigned to **n2**. The value of **d2** is not affected. The value 1 is assigned to **i**. |

[19] In these examples, multibyte characters do have a state-dependent encoding, and multibyte members of the extended character set consist of two bytes, the first of which is denoted here by a **$0** and the second by an uppercase letter, but are only recognized as such when in the alternate shift state. The shift sequences are denoted by ↑ and ↓, in which the first causes entry into the alternate shift state.

1. After the call:

```
#include <stdio.h>
/*...*/
char str[50];
fscanf(stdin, "a%s", str);
```

with the input line: |

```
a↑$0X$0Y↓ bc
```

str will contain ↑**$0X$0Y**↓**\0** assuming that none of the bytes of the shift sequences (or of the multibyte characters, in the more general case) appears to be a single-byte white-space character. |

2. In contrast, after the call:

```
#include <stdio.h>
#include <stddef.h>
/*...*/
wchar_t wstr[50];
fscanf(stdin, "a%ls", wstr);
```

with the same input line, **wstr** will contain the two wide characters that correspond to **$0X** and **$0Y** and a terminating null wide character. |

3. However, the call:

```
#include <stdio.h>
#include <stddef.h>
/*...*/
wchar_t wstr[50];
fscanf(stdin, "a↑$0X↓%ls", wstr);
```

with the same input line will return zero due to a matching failure against the ↓ sequence in the format string.

4. Assuming that the first byte of the multibyte character **$0X** is the same as the first byte of the multibyte character **$0Y**, after the call:

```
#include <stdio.h>
#include <stddef.h>
/*...*/
wchar_t wstr[50];
fscanf(stdin, "a↑$0Y↓%ls", wstr);
```

with the same input line, zero will again be returned, but **stdin** will be left with a partially consumed multibyte character.

Forward references: the **strtod** function (7.12.1.4), the **strtol** function (7.12.1.5), the **strtoul** function (7.12.1.6), conversion state (7.17.6), the **wcrtomb** function (7.17.6.3.3).

7.11.6.3 The printf function

Synopsis

[1]

```
#include <stdio.h>
int printf(const char * restrict format, ...);
```

Description

[2] The **printf** function is equivalent to **fprintf** with the argument **stdout** interposed before the arguments to **printf**.

Returns

[3] The **printf** function returns the number of characters transmitted, or a negative value if an output error occurred.

7.11.6.4 The scanf function

Synopsis

[1]

```
#include <stdio.h>
int scanf(const char * restrict format, ...);
```

Description

[2] The **scanf** function is equivalent to **fscanf** with the argument **stdin** interposed before the arguments to **scanf**.

Returns

[3] The **scanf** function returns the value of the macro **EOF** if an input failure occurs before any conversion. Otherwise, the **`scanf`** function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early matching failure.

7.11.6.5 The `sprintf` function

Synopsis

[1]

```
#include <stdio.h>
int sprintf(char * restrict s,
     const char * restrict format, ...);
```

Description

[2] The **`sprintf`** function is equivalent to **`fprintf`**, except that the argument **`s`** specifies an array into which the generated output is to be written, rather than to a stream. A null character is written at the end of the characters written; it is not counted as part of the returned sum. If copying takes place between objects that overlap, the behavior is undefined.

Returns

[3] The **`sprintf`** function returns the number of characters written in the array, not counting the terminating null character.

7.11.6.6 The `sscanf` function

Synopsis

[1]

```
#include <stdio.h>
int sscanf(const char * restrict s,
     const char * restrict format, ...);
```

Description

[2] The **`sscanf`** function is equivalent to **`fscanf`**, except that the argument **`s`** specifies a string from which the input is to be obtained, rather than from a stream. Reaching the end of the string is equivalent to encountering end-of-file for the **`fscanf`** function. If copying takes place between objects that overlap, the behavior is undefined.

Returns

[3] The **`sscanf`** function returns the value of the macro **`EOF`** if an input failure occurs before any conversion. Otherwise, the **`sscanf`** function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early matching failure.

7.11.6.7 The `vfprintf` function

Synopsis

[1]

```
#include <stdarg.h>
#include <stdio.h>
int vfprintf(FILE * restrict stream,
     const char * restrict format,
     va_list arg);
```

Description

[2] The **vfprintf** function is equivalent to **fprintf**, with the variable argument list replaced by **arg**, which shall have been initialized by the **va_start** macro (and possibly subsequent **va_arg** calls). The **vfprintf** function does not invoke the **va_end** macro.[166]

Returns

[3] The **vfprintf** function returns the number of characters transmitted, or a negative value if an output error occurred.

Example

[4] The following shows the use of the **vfprintf** function in a general error-reporting routine.

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

void error(char *function_name, char *format, ...)
{
     va_list args;

     va_start(args, format);
     /* print out name of function causing error */
     fprintf(stderr, "ERROR in %s: ", function_name);
     /* print out remainder of message */
     vfprintf(stderr, format, args);
     va_end(args);
}
```

166. As the functions **vfprintf**, **vsprintf**, and **vprintf** invoke the **va_arg** macro, the value of **arg** after the return is indeterminate.

7.11.6.8 The `vprintf` function

Synopsis

[1]

```
#include <stdarg.h>
#include <stdio.h>
int vprintf(const char * restrict format,
     va_list arg);
```

Description

[2] The **`vprintf`** function is equivalent to **`printf`**, with the variable argument list replaced by **`arg`**, which shall have been initialized by the **`va_start`** macro (and possibly subsequent **`va_arg`** calls). The **`vprintf`** function does not invoke the **`va_end`** macro.[166]

Returns

[3] The **`vprintf`** function returns the number of characters transmitted, or a negative value if an output error occurred.

7.11.6.9 The `vsprintf` function

Synopsis

[1]

```
#include <stdarg.h>
#include <stdio.h>
int vsprintf(char * restrict s,
     const char * restrict format,
     va_list arg);
```

Description

[2] The **`vsprintf`** function is equivalent to **`sprintf`**, with the variable argument list replaced by **`arg`**, which shall have been initialized by the **`va_start`** macro (and possibly subsequent **`va_arg`** calls). The **`vsprintf`** function does not invoke the **`va_end`** macro.[166] If copying takes place between objects that overlap, the behavior is undefined.

Returns

[3] The **`vsprintf`** function returns the number of characters written in the array, not counting the terminating null character.

7.11.7 Character input/output functions

7.11.7.1 The `fgetc` function

Synopsis

[1]

```
#include <stdio.h>
int fgetc(FILE *stream);
```

Description

[2] The **`fgetc`** function obtains the next character (if present) as an **`unsigned char`** converted to an **`int`**, from the input stream pointed to by **`stream`**, and advances the associated file position indicator for the stream (if defined).

Returns

[3] The **`fgetc`** function returns the next character from the input stream pointed to by **`stream`**. If the stream is at end-of-file, the end-of-file indicator for the stream is set and **`fgetc`** returns **`EOF`**. If a read error occurs, the error indicator for the stream is set and **`fgetc`** returns **`EOF`**.[167]

7.11.7.2 The `fgets` function

Synopsis

[1]

```
#include <stdio.h>
char *fgets(char * restrict s, int n,
     FILE * restrict stream);
```

Description

[2] The **`fgets`** function reads at most one less than the number of characters specified by **`n`** from the stream pointed to by **`stream`** into the array pointed to by **`s`**. No additional characters are read after a new-line character (which is retained) or after end-of-file. A null character is written immediately after the last character read into the array.

Returns

[3] The **`fgets`** function returns **`s`** if successful. If end-of-file is encountered and no characters have been read into the array, the contents of the array remain unchanged and a null pointer is returned. If a read error occurs during the operation, the array contents are indeterminate and a null pointer is returned.

167. An end-of-file and a read error can be distinguished by use of the **`feof`** and **`ferror`** functions.

7.11.7.3 The `fputc` function

Synopsis

[1]

```
#include <stdio.h>
int fputc(int c, FILE *stream);
```

Description

[2] The **fputc** function writes the character specified by **c** (converted to an **unsigned char**) to the output stream pointed to by **stream**, at the position indicated by the associated file position indicator for the stream (if defined), and advances the indicator appropriately. If the file cannot support positioning requests, or if the stream was opened with append mode, the character is appended to the output stream.

Returns

[3] The **fputc** function returns the character written. If a write error occurs, the error indicator for the stream is set and **fputc** returns **EOF**.

7.11.7.4 The `fputs` function

Synopsis

[1]

```
#include <stdio.h>
int fputs(const char * restrict s,
     FILE * restrict stream);
```

Description

[2] The **fputs** function writes the string pointed to by **s** to the stream pointed to by **stream**. The terminating null character is not written.

Returns

[3] The **fputs** function returns **EOF** if a write error occurs; otherwise it returns a nonnegative value.

7.11.7.5 The `getc` function

Synopsis

[1]

```
#include <stdio.h>
int getc(FILE *stream);
```

Description

[2] The **getc** function is equivalent to **fgetc**, except that if it is implemented as a macro, it may evaluate **stream** more than once, so the argument should never be an expression with side effects.

Returns

[3] The **`getc`** function returns the next character from the input stream pointed to by **`stream`**. If the stream is at end-of-file, the end-of-file indicator for the stream is set and **`getc`** returns **`EOF`**. If a read error occurs, the error indicator for the stream is set and **`getc`** returns **`EOF`**.

7.11.7.6 The `getchar` function

Synopsis

[1]

```
#include <stdio.h>
int getchar(void);
```

Description

[2] The **`getchar`** function is equivalent to **`getc`** with the argument **`stdin`**.

Returns

[3] The **`getchar`** function returns the next character from the input stream pointed to by **`stdin`**. If the stream is at end-of-file, the end-of-file indicator for the stream is set and **`getchar`** returns **`EOF`**. If a read error occurs, the error indicator for the stream is set and **`getchar`** returns **`EOF`**.

7.11.7.7 The `gets` function

Synopsis

[1]

```
#include <stdio.h>
char *gets(char *s);
```

Description

[2] The **`gets`** function reads characters from the input stream pointed to by **`stdin`**, into the array pointed to by **`s`**, until end-of-file is encountered or a new-line character is read. Any new-line character is discarded, and a null character is written immediately after the last character read into the array.

Returns

[3] The **`gets`** function returns **`s`** if successful. If end-of-file is encountered and no characters have been read into the array, the contents of the array remain unchanged and a null pointer is returned. If a read error occurs during the operation, the array contents are indeterminate and a null pointer is returned.

7.11.7.8 The `putc` function

Synopsis

[1]

```
#include <stdio.h>
int putc(int c, FILE *stream);
```

Description

[2] The **putc** function is equivalent to **fputc**, except that if it is implemented as a macro, it may evaluate **stream** more than once, so the argument should never be an expression with side effects.

Returns

[3] The **putc** function returns the character written. If a write error occurs, the error indicator for the stream is set and **putc** returns **EOF**.

7.11.7.9 The `putchar` function

Synopsis

[1]

```
#include <stdio.h>
int putchar(int c);
```

Description

[2] The **putchar** function is equivalent to **putc** with the second argument **stdout**.

Returns

[3] The **putchar** function returns the character written. If a write error occurs, the error indicator for the stream is set and **putchar** returns **EOF**.

7.11.7.10 The `puts` function

Synopsis

[1]

```
#include <stdio.h>
int puts(const char *s);
```

Description

[2] The **puts** function writes the string pointed to by **s** to the stream pointed to by **stdout**, and appends a new-line character to the output. The terminating null character is not written.

Returns

[3] The **puts** function returns **EOF** if a write error occurs; otherwise it returns a nonnegative value.

7.11.7.11 The **ungetc** function

Synopsis

[1]

```
#include <stdio.h>
int ungetc(int c, FILE *stream);
```

Description

[2] The **ungetc** function pushes the character specified by **c** (converted to an **unsigned char**) back onto the input stream pointed to by **stream**. The pushed-back characters will be returned by subsequent reads on that stream in the reverse order of their pushing. A successful intervening call (with the stream pointed to by **stream**) to a file positioning function (**fseek**, **fsetpos**, or **rewind**) discards any pushed-back characters for the stream. The external storage corresponding to the stream is unchanged.

[3] One character of pushback is guaranteed. If the **ungetc** function is called too many times on the same stream without an intervening read or file positioning operation on that stream, the operation may fail.

[4] If the value of **c** equals that of the macro **EOF**, the operation fails and the input stream is unchanged.

[5] A successful call to the **ungetc** function clears the end-of-file indicator for the stream. The value of the file position indicator for the stream after reading or discarding all pushed-back characters shall be the same as it was before the characters were pushed back. For a text stream, the value of its file position indicator after a successful call to the **ungetc** function is unspecified until all pushed-back characters are read or discarded. For a binary stream, its file position indicator is decremented by each successful call to the **ungetc** function; if its value was zero before a call, it is indeterminate after the call.

Returns

[6] The **ungetc** function returns the character pushed back after conversion, or **EOF** if the operation fails.

Forward references: file positioning functions (7.11.9).

7.11.8 Direct input/output functions

7.11.8.1 The `fread` function

Synopsis

[1]

```
#include <stdio.h>
size_t fread(void * restrict ptr,
     size_t size, size_t nmemb,
     FILE * restrict stream);
```

Description

[2] The **fread** function reads, into the array pointed to by **ptr**, up to **nmemb** elements whose size is specified by **size**, from the stream pointed to by **stream**. The file position indicator for the stream (if defined) is advanced by the number of characters successfully read. If an error occurs, the resulting value of the file position indicator for the stream is indeterminate. If a partial element is read, its value is indeterminate.

Returns

[3] The **fread** function returns the number of elements successfully read, which may be less than **nmemb** if a read error or end-of-file is encountered. If **size** or **nmemb** is zero, **fread** returns zero and the contents of the array and the state of the stream remain unchanged.

7.11.8.2 The `fwrite` function

Synopsis

[1]

```
#include <stdio.h>
size_t fwrite(const void * restrict ptr,
     size_t size, size_t nmemb,
     FILE * restrict stream);
```

Description

[2] The **fwrite** function writes, from the array pointed to by **ptr**, up to **nmemb** elements whose size is specified by **size**, to the stream pointed to by **stream**. The file position indicator for the stream (if defined) is advanced by the number of characters successfully written. If an error occurs, the resulting value of the file position indicator for the stream is indeterminate.

Returns

[3] The **fwrite** function returns the number of elements successfully written, which will be less than **nmemb** only if a write error is encountered.

7.11.9 File positioning functions

7.11.9.1 The `fgetpos` function

Synopsis

[1]

```
#include <stdio.h>
int fgetpos(FILE * restrict stream,
     fpos_t * restrict pos);
```

Description

[2] The **fgetpos** function stores the current value of the file position indicator for the stream pointed to by **stream** in the object pointed to by **pos**. The value stored contains unspecified information usable by the **fsetpos** function for repositioning the stream to its position at the time of the call to the **fgetpos** function.

Returns

[3] If successful, the **fgetpos** function returns zero; on failure, the **fgetpos** function returns nonzero and stores an implementation-defined positive value in **errno**.

Forward references: the **fsetpos** function (7.11.9.3).

7.11.9.2 The `fseek` function

Synopsis

[1]

```
#include <stdio.h>
int fseek(FILE *stream, long int offset, int whence);
```

Description

[2] The **fseek** function sets the file position indicator for the stream pointed to by **stream**.

[3] For a binary stream, the new position, measured in characters from the beginning of the file, is obtained by adding **offset** to the position specified by **whence**. The specified position is the beginning of the file if **whence** is **SEEK_SET**, the current value of the file position indicator if **SEEK_CUR**, or end-of-file if **SEEK_END**. A binary stream need not meaningfully support **fseek** calls with a **whence** value of **SEEK_END**.

[4] For a text stream, either **offset** shall be zero, or **offset** shall be a value returned by an earlier successful call to the **ftell** function on the same stream and **whence** shall be **SEEK_SET**. *

[5] A successful call to the **fseek** function clears the end-of-file indicator for the stream and undoes any effects of the **ungetc** function on the same stream. After an

fseek call, the next operation on an update stream may be either input or output.

Returns

[6] The **fseek** function returns nonzero only for a request that cannot be satisfied.

Forward references: the **ftell** function (7.11.9.4).

7.11.9.3 The fsetpos function

Synopsis

[1]

```
#include <stdio.h>
int fsetpos(FILE *stream, const fpos_t *pos);
```

Description

[2] The **fsetpos** function sets the file position indicator for the stream pointed to by **stream** according to the value of the object pointed to by **pos**, which shall be a value obtained from an earlier successful call to the **fgetpos** function on the same stream.

[3] A successful call to the **fsetpos** function clears the end-of-file indicator for the stream and undoes any effects of the **ungetc** function on the same stream. After an **fsetpos** call, the next operation on an update stream may be either input or output.

Returns

[4] If successful, the **fsetpos** function returns zero; on failure, the **fsetpos** function returns nonzero and stores an implementation-defined positive value in **errno**.

7.11.9.4 The ftell function

Synopsis

[1]

```
#include <stdio.h>
long int ftell(FILE *stream);
```

Description

[2] The **ftell** function obtains the current value of the file position indicator for the stream pointed to by **stream**. For a binary stream, the value is the number of characters from the beginning of the file. For a text stream, its file position indicator contains unspecified information, usable by the **fseek** function for returning the file position indicator for the stream to its position at the time of the **ftell** call; the difference between two such return values is not necessarily a meaningful measure of the number of characters written or read.

Returns

[3] If successful, the **`ftell`** function returns the current value of the file position indicator for the stream. On failure, the **`ftell`** function returns −1L and stores an implementation-defined positive value in **`errno`**.

7.11.9.5 The `rewind` function

Synopsis

[1]

```
#include <stdio.h>
void rewind(FILE *stream);
```

Description

[2] The **`rewind`** function sets the file position indicator for the stream pointed to by **`stream`** to the beginning of the file. It is equivalent to

```
(void)fseek(stream, 0L, SEEK_SET)
```

except that the error indicator for the stream is also cleared.

Returns

[3] The **`rewind`** function returns no value.

7.11.10 Error-handling functions

7.11.10.1 The `clearerr` function

Synopsis

[1]

```
#include <stdio.h>
void clearerr(FILE *stream);
```

Description

[2] The **`clearerr`** function clears the end-of-file and error indicators for the stream pointed to by **`stream`**.

Returns

[3] The **`clearerr`** function returns no value.

7.11.10.2 The `feof` function

Synopsis

[1]

```
#include <stdio.h>
int feof(FILE *stream);
```

Description

[2] The **`feof`** function tests the end-of-file indicator for the stream pointed to by

stream.

Returns

[3] The **feof** function returns nonzero if and only if the end-of-file indicator is set for **stream**.

7.11.10.3 The ferror function

Synopsis

[1]

```
#include <stdio.h>
int ferror(FILE *stream);
```

Description

[2] The **ferror** function tests the error indicator for the stream pointed to by **stream**.

Returns

[3] The **ferror** function returns nonzero if and only if the error indicator is set for **stream**.

7.11.10.4 The perror function

Synopsis

[1]

```
#include <stdio.h>
void perror(const char *s);
```

Description

[2] The **perror** function maps the error number in the integer expression **errno** to an error message. It writes a sequence of characters to the standard error stream thus: first (if **s** is not a null pointer and the character pointed to by **s** is not the null character), the string pointed to by **s** followed by a colon (**:**) and a space; then an appropriate error message string followed by a new-line character. The contents of the error message strings are the same as those returned by the **strerror** function with argument **errno**, which are implementation-defined.

Returns

[3] The **perror** function returns no value.

Forward references: the **strerror** function (7.13.6.2).

7.12 General utilities **<stdlib.h>**

[1] The header **<stdlib.h>** declares four types and several functions of general utility, and defines several macros.[168]

[2] The types declared are **size_t** and **wchar_t** (both described in 7.1.6),

div_t

which is a structure type that is the type of the value returned by the **div** function, *

ldiv_t

which is a structure type that is the type of the value returned by the **ldiv** function, and

lldiv_t

which is a structure type that is the type of the value returned by the **lldiv** function.

[3] The macros defined are **NULL** (described in 7.1.6);

EXIT_FAILURE

and

EXIT_SUCCESS

which expand to integral expressions that may be used as the argument to the **exit** function to return unsuccessful or successful termination status, respectively, to the host environment;

RAND_MAX

which expands to an integral constant expression, the value of which is the maximum value returned by the **rand** function; and

MB_CUR_MAX

which expands to a positive integer expression whose value is the maximum number of bytes in a multibyte character for the extended character set specified by the current locale (category **LC_CTYPE**), and whose value is never greater than **MB_LEN_MAX**.

168. See ‘‘future library directions’’ (7.18.7).

7.12.1 String conversion functions

[1] The functions **atof**, **atoi**, **atol**, and **atoll** need not affect the value of the integer expression **errno** on an error. If the value of the result cannot be represented, the behavior is undefined.

7.12.1.1 The atof function

Synopsis

[1]

```
#include <stdlib.h>
double atof(const char *nptr);
```

Description

[2] The **atof** function converts the initial portion of the string pointed to by **nptr** to **double** representation. Except for the behavior on error, it is equivalent to

```
strtod(nptr, (char **)NULL)
```

Returns

[3] The **atof** function returns the converted value.

Forward references: the **strtod** function (7.12.1.4).

7.12.1.2 The atoi function

Synopsis

[1]

```
#include <stdlib.h>
int atoi(const char *nptr);
```

Description

[2] The **atoi** function converts the initial portion of the string pointed to by **nptr** to **int** representation. Except for the behavior on error, it is equivalent to

```
(int)strtol(nptr, (char **)NULL, 10)
```

Returns

[3] The **atoi** function returns the converted value.

Forward references: the **strtol** function (7.12.1.5).

7.12.1.3 The `atol` function

Synopsis

[1]

```
#include <stdlib.h>
long int atol(const char *nptr);
```

Description

[2] The **atol** function converts the initial portion of the string pointed to by **nptr** to **long int** representation. Except for the behavior on error, it is equivalent to

```
strtol(nptr, (char **)NULL, 10)
```

Returns

[3] The **atol** function returns the converted value.

Forward references: the **strtol** function (7.12.1.5).

7.12.1.4 The `atoll` function

Synopsis

[1]

```
#include <stdlib.h>
long long int atoll(const char *nptr);
```

Description

[2] The **atoll** function converts the initial portion of the string pointed to by **nptr** to **long long int** representation. Except for the behavior on error, it is equivalent to

```
strtoll(nptr, (char **)NULL, 10)
```

Returns

[3] The **atoll** function returns the converted value.

Forward references: the **strtol** function (7.12.1.5).

7.12.1.5 The `strtod` function

Synopsis

[1]

```
#include <stdlib.h>
double strtod(const char * restrict nptr,
     char ** restrict endptr);
```

Description

[2] The **strtod** function converts the initial portion of the string pointed to by **nptr**

to **double** representation. First, it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space characters (as specified by the **isspace** function), a subject sequence resembling a floating-point constant; and a final string of one or more unrecognized characters, including the terminating null character of the input string. Then, it attempts to convert the subject sequence to a floating-point number, and returns the result.

[3]

The expected form of the subject sequence is an optional plus or minus sign, then one of the following:

— a nonempty sequence of decimal digits optionally containing a decimal-point character, then an optional exponent part as defined in 6.1.3.1;

— a 0x or 0X, then a nonempty sequence of hexadecimal digits optionally containing a decimal-point character, then an optional binary-exponent part, where either the decimal-point character or the binary-exponent part is present;

but no floating suffix. The subject sequence is defined as the longest initial subsequence of the input string, starting with the first non-white-space character, that is of the expected form. The subject sequence contains no characters if the input string is empty or consists entirely of white space, or if the first non-white-space character is other than a sign, a digit, or a decimal-point character.

[4] If the subject sequence has the expected form, the sequence of characters starting with the first digit or the decimal-point character (whichever occurs first) is interpreted as a floating constant according to the rules of 6.1.3.1, except that the decimal-point character is used in place of a period, and that if neither an exponent part, a binary-exponent part, nor a decimal-point character appears, a decimal point is assumed to follow the last digit in the string. If the subject sequence begins with a minus sign, the value resulting from the conversion is negated. A pointer to the final string is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

[5] In other than the **"C"** locale, additional locale-specific subject sequence forms may be accepted.

[6] If the subject sequence is empty or does not have the expected form, no conversion is performed; the value of **nptr** is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

[7] If the subject sequence has the hexadecimal form and **FLT_RADIX** is a power of 2, then the value resulting from the conversion is correctly rounded.

Recommended practice

[8] If the subject sequence has the hexadecimal form and **FLT_RADIX** is not a power of 2, then the result is one of the two numbers in the appropriate internal format that are adjacent to the hexadecimal floating source value, with the extra stipulation that the error have a correct sign for the current rounding direction.

Returns

[9] The **`strtod`** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, plus or minus **`HUGE_VAL`** is returned (according to the sign of the value), and the value of the macro **`ERANGE`** is stored in **`errno`**. If the correct value would cause underflow, zero is returned and the value of the macro **`ERANGE`** is stored in **`errno`**.

7.12.1.6 The `strtol` function

Synopsis

[1]

```
#include <stdlib.h>
long int strtol(const char * restrict nptr,
     char ** restrict endptr, int base);
```

Description

[2] The **`strtol`** function converts the initial portion of the string pointed to by **`nptr`** to **`long int`** representation. First, it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space characters (as specified by the **`isspace`** function), a subject sequence resembling an integer represented in some radix determined by the value of **`base`**, and a final string of one or more unrecognized characters, including the terminating null character of the input string. Then, it attempts to convert the subject sequence to an integer, and returns the result.

[3] If the value of **`base`** is zero, the expected form of the subject sequence is that of an integer constant as described in 6.1.3.2, optionally preceded by a plus or minus sign, but not including an integer suffix. If the value of **`base`** is between 2 and 36, the expected form of the subject sequence is a sequence of letters and digits representing an integer with the radix specified by **`base`**, optionally preceded by a plus or minus sign, but not including an integer suffix. The letters from **`a`** (or **`A`**) through **`z`** (or **`Z`**) are ascribed the values 10 to 35; only letters whose ascribed values are less than that of **`base`** are permitted. If the value of **`base`** is 16, the characters **`0x`** or **`0X`** may optionally precede the sequence of letters and digits, following the sign if present.

[4] The subject sequence is defined as the longest initial subsequence of the input string, starting with the first non-white-space character, that is of the expected form. The subject sequence contains no characters if the input string is empty or consists entirely of white space, or if the first non-white-space character is other than a sign or a permissible letter or digit.

[5] If the subject sequence has the expected form and the value of **`base`** is zero, the sequence of characters starting with the first digit is interpreted as an integer constant according to the rules of 6.1.3.2. If the subject sequence has the expected form and the value of **`base`** is between 2 and 36, it is used as the base for conversion, ascribing to each letter its value as given above. If the subject sequence begins with a minus sign, the value resulting from the conversion is negated. A pointer to the final string is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

[6] In other than the **"C"** locale, additional locale-specific subject sequence forms may be accepted.

[7] If the subject sequence is empty or does not have the expected form, no conversion is performed; the value of **nptr** is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

Returns

[8] The **strtol** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, **LONG_MAX** or **LONG_MIN** is returned (according to the sign of the value), and the value of the macro **ERANGE** is stored in **errno**.

7.12.1.7 The strtoll function

Synopsis

[1]

```
#include <stdlib.h>
long long int strtol(const char * restrict nptr,
     char ** restrict endptr, int base);
```

Description

[2] The **strtoll** is equivalent to the **strtol** function, except that it converts the initial portion of the string pointed to by **nptr** to **long long int** representation.

Returns

[3] The **strtoll** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, **LLONG_MAX** or **LLONG_MIN** is returned (according to the sign of the value), and the value of the macro **ERANGE** is stored in **errno**.

7.12.1.8 The strtoul function

Synopsis

[1]

```
#include <stdlib.h>
unsigned long int strtoul(
     const char * restrict nptr,
     char ** restrict endptr,
     int base);
```

Description

[2] The **`strtoul`** function converts the initial portion of the string pointed to by **`nptr`** to **`unsigned long int`** representation. First, it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space characters (as specified by the **`isspace`** function), a subject sequence resembling an unsigned integer represented in some radix determined by the value of **`base`**, and a final string of one or more unrecognized characters, including the terminating null character of the input string. Then, it attempts to convert the subject sequence to an unsigned integer, and returns the result.

[3] If the value of **`base`** is zero, the expected form of the subject sequence is that of an integer constant as described in 6.1.3.2, optionally preceded by a plus or minus sign, but not including an integer suffix. If the value of **`base`** is between 2 and 36, the expected form of the subject sequence is a sequence of letters and digits representing an integer with the radix specified by **`base`**, optionally preceded by a plus or minus sign, but not including an integer suffix. The letters from **`a`** (or **`A`**) through **`z`** (or **`Z`**) are ascribed the values 10 to 35; only letters whose ascribed values are less than that of **`base`** are permitted. If the value of **`base`** is 16, the characters **`0x`** or **`0X`** may optionally precede the sequence of letters and digits, following the sign if present.

[4] The subject sequence is defined as the longest initial subsequence of the input string, starting with the first non-white-space character, that is of the expected form. The subject sequence contains no characters if the input string is empty or consists entirely of white space, or if the first non-white-space character is other than a sign or a permissible letter or digit.

[5] If the subject sequence has the expected form and the value of **`base`** is zero, the sequence of characters starting with the first digit is interpreted as an integer constant according to the rules of 6.1.3.2. If the subject sequence has the expected form and the value of **`base`** is between 2 and 36, it is used as the base for conversion, ascribing to each letter its value as given above. If the subject sequence begins with a minus sign, the value resulting from the conversion is negated. A pointer to the final string is stored in the object pointed to by **`endptr`**, provided that **`endptr`** is not a null pointer.

[6] In other than the **`"C"`** locale, additional locale-specific subject sequence forms may be accepted.

[7] If the subject sequence is empty or does not have the expected form, no conversion is performed; the value of **`nptr`** is stored in the object pointed to by **`endptr`**, provided that **`endptr`** is not a null pointer.

Returns

[8] The **`strtoul`** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, **`ULONG_MAX`** is returned, and the value of the macro **`ERANGE`** is stored in **`errno`**.

7.12.1.9 The **strtoull** function

Synopsis

[1]

```
#include <stdlib.h>
unsigned long long int strtoull(
     const char * restrict nptr,
     char ** restrict endptr,
     int base);
```

Description

[2] The **strtoull** is equivalent to the **strtoul** function, except that it converts the initial portion of the string pointed to by **nptr** to **unsigned long long int** representation.

Returns

[3] The **strtoull** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, **ULLONG_MAX** is returned, and the value of the macro **ERANGE** is stored in **errno**.

7.12.2 Pseudo-random sequence generation functions

7.12.2.1 The **rand** function

Synopsis

[1]

```
#include <stdlib.h>
int rand(void);
```

Description

[2] The **rand** function computes a sequence of pseudo-random integers in the range 0 to **RAND_MAX**.

[3] The implementation shall behave as if no library function calls the **rand** function.

Returns

[4] The **rand** function returns a pseudo-random integer.

Environmental limit

[5] The value of the **RAND_MAX** macro shall be at least 32767.

7.12.2.2 The `srand` function

Synopsis

[1]

```
#include <stdlib.h>
void srand(unsigned int seed);
```

Description

[2] The **`srand`** function uses the argument as a seed for a new sequence of pseudo-random numbers to be returned by subsequent calls to **`rand`**. If **`srand`** is then called with the same seed value, the sequence of pseudo-random numbers shall be repeated. If **`rand`** is called before any calls to **`srand`** have been made, the same sequence shall be generated as when **`srand`** is first called with a seed value of 1.

[3] The implementation shall behave as if no library function calls the **`srand`** function.

Returns

[4] The **`srand`** function returns no value.

Example

[5] The following functions define a portable implementation of **`rand`** and **`srand`**.

```
static unsigned long int next = 1;

int rand(void)   /* RAND_MAX assumed to be 32767 */
{
     next = next * 1103515245 + 12345;
     return (unsigned int)(next/65536) % 32768;
}

void srand(unsigned int seed)
{
     next = seed;
}
```

7.12.3 Memory management functions

[1] The order and contiguity of storage allocated by successive calls to the **`calloc`**, **`malloc`**, and **`realloc`** functions is unspecified. The pointer returned if the allocation succeeds is suitably aligned so that it may be assigned to a pointer to any type of object and then used to access such an object or an array of such objects in the space allocated (until the space is explicitly freed or reallocated). Each such allocation shall yield a pointer to an object disjoint from any other object. The pointer returned points to the start (lowest byte address) of the allocated space. If the space cannot be allocated, a null pointer is returned. If the size of the space requested is zero, the behavior is implementation-defined; the value returned shall be either a null pointer or a unique pointer. The value of a pointer that refers to freed space is indeterminate.

7.12.3.1 The `calloc` function

Synopsis

[1]

```
#include <stdlib.h>
void *calloc(size_t nmemb, size_t size);
```

Description

[2] The **`calloc`** function allocates space for an array of **`nmemb`** objects, each of whose size is **`size`**. The space is initialized to all bits zero.[169]

Returns

[3] The **`calloc`** function returns either a null pointer or a pointer to the allocated space.

7.12.3.2 The `free` function

Synopsis

[1]

```
#include <stdlib.h>
void free(void *ptr);
```

Description

[2] The **`free`** function causes the space pointed to by **`ptr`** to be deallocated, that is, made available for further allocation. If **`ptr`** is a null pointer, no action occurs. Otherwise, if the argument does not match a pointer earlier returned by the **`calloc`**, **`malloc`**, or **`realloc`** function, or if the space has been deallocated by a call to **`free`** or **`realloc`**, the behavior is undefined.

Returns

[3] The **`free`** function returns no value.

169. Note that this need not be the same as the representation of floating-point zero or a null pointer constant.

7.12.3.3 The `malloc` function

Synopsis

[1]

```
#include <stdlib.h>
void *malloc(size_t size);
```

Description

[2] The **`malloc`** function allocates space for an object whose size is specified by **`size`** and whose value is indeterminate.

Returns

[3] The **`malloc`** function returns either a null pointer or a pointer to the allocated space.

7.12.3.4 The `realloc` function

Synopsis

[1]

```
#include <stdlib.h>
void *realloc(void *ptr, size_t size);
```

Description

[2] The **`realloc`** function changes the size of the object pointed to by **`ptr`** to the size specified by **`size`**. The contents of the object shall be unchanged up to the lesser of the new and old sizes. If the new size is larger, the value of the newly allocated portion of the object is indeterminate. If **`ptr`** is a null pointer, the **`realloc`** function behaves like the **`malloc`** function for the specified size. Otherwise, if **`ptr`** does not match a pointer earlier returned by the **`calloc`**, **`malloc`**, or **`realloc`** function, or if the space has been deallocated by a call to the **`free`** or **`realloc`** function, the behavior is undefined. If the space cannot be allocated, the object pointed to by **`ptr`** is unchanged. If **`size`** is zero and **`ptr`** is not a null pointer, the object it points to is freed.

Returns

[3] The **`realloc`** function returns either a null pointer or a pointer to the possibly moved allocated space.

7.12.4 Communication with the environment

7.12.4.1 The `abort` function

Synopsis

[1]

```
#include <stdlib.h>
void abort(void);
```

Description

[2] The **`abort`** function causes abnormal program termination to occur, unless the signal **`SIGABRT`** is being caught and the signal handler does not return. Whether open output streams are flushed or open streams closed or temporary files removed is implementation-defined. An implementation-defined form of the status *unsuccessful termination* is returned to the host environment by means of the function call **`raise(SIGABRT)`**.

Returns

[3] The **`abort`** function cannot return to its caller.

7.12.4.2 The `atexit` function

Synopsis

[1]

```
#include <stdlib.h>
int atexit(void (*func)(void));
```

Description

[2] The **`atexit`** function registers the function pointed to by **`func`**, to be called without arguments at normal program termination.

Implementation limits

[3] The implementation shall support the registration of at least 32 functions.

Returns

[4] The **`atexit`** function returns zero if the registration succeeds, nonzero if it fails.

Forward references: the **`exit`** function (7.12.4.3).

7.12.4.3 The `exit` function

Synopsis

[1]

```
#include <stdlib.h>
void exit(int status);
```

Description

[2] The **exit** function causes normal program termination to occur. If more than one call to the **exit** function is executed by a program, the behavior is undefined.

[3] First, all functions registered by the **atexit** function are called, in the reverse order of their registration.[170]

[4] Next, all open streams with unwritten buffered data are flushed, all open streams are closed, and all files created by the **tmpfile** function are removed.

[5] Finally, control is returned to the host environment. If the value of **status** is zero or **EXIT_SUCCESS**, an implementation-defined form of the status *successful termination* is returned. If the value of **status** is **EXIT_FAILURE**, an implementation-defined form of the status *unsuccessful termination* is returned. Otherwise the status returned is implementation-defined.

Returns

[6] The **exit** function cannot return to its caller.

7.12.4.4 The getenv function

Synopsis

[1]

```
#include <stdlib.h>
char *getenv(const char *name);
```

Description

[2] The **getenv** function searches an *environment list*, provided by the host environment, for a string that matches the string pointed to by **name**. The set of environment names and the method for altering the environment list are implementation-defined.

[3] The implementation shall behave as if no library function calls the **getenv** function.

Returns

[4] The **getenv** function returns a pointer to a string associated with the matched list member. The string pointed to shall not be modified by the program, but may be overwritten by a subsequent call to the **getenv** function. If the specified **name** cannot be found, a null pointer is returned.

170. Each function is called as many times as it was registered.

7.12.4.5 The `system` function

Synopsis

[1]

```
#include <stdlib.h>
int system(const char *string);
```

Description

[2] The **`system`** function passes the string pointed to by **`string`** to the host environment to be executed by a *command processor* in an implementation-defined manner. A null pointer may be used for **`string`** to inquire whether a command processor exists.

Returns

[3] If the argument is a null pointer, the **`system`** function returns nonzero only if a command processor is available. If the argument is not a null pointer, the **`system`** function returns an implementation-defined value.

7.12.5 Searching and sorting utilities

7.12.5.1 The `bsearch` function

Synopsis

[1]

```
#include <stdlib.h>
void *bsearch(const void *key, const void *base,
     size_t nmemb, size_t size,
     int (*compar)(const void *, const void *));
```

Description

[2] The **`bsearch`** function searches an array of **`nmemb`** objects, the initial element of which is pointed to by **`base`**, for an element that matches the object pointed to by **`key`**. The size of each element of the array is specified by **`size`**.

[3] The comparison function pointed to by **`compar`** is called with two arguments that point to the **`key`** object and to an array element, in that order. The function shall return an integer less than, equal to, or greater than zero if the **`key`** object is considered, respectively, to be less than, to match, or to be greater than the array element. The array shall consist of: all the elements that compare less than, all the elements that compare equal to, and all the elements that compare greater than the **`key`** object, in that order.[171]

---

171. In practice, the entire array is sorted according to the comparison function.

Returns

[4] The **bsearch** function returns a pointer to a matching element of the array, or a null pointer if no match is found. If two elements compare as equal, which element is matched is unspecified.

7.12.5.2 The qsort function

Synopsis

[1]

```
#include <stdlib.h>
void qsort(void *base, size_t nmemb, size_t size,
     int (*compar)(const void *, const void *));
```

Description

[2] The **qsort** function sorts an array of **nmemb** objects, the initial element of which is pointed to by **base**. The size of each object is specified by **size**.

[3] The contents of the array are sorted into ascending order according to a comparison function pointed to by **compar**, which is called with two arguments that point to the objects being compared. The function shall return an integer less than, equal to, or greater than zero if the first argument is considered to be respectively less than, equal to, or greater than the second.

[4] If two elements compare as equal, their order in the sorted array is unspecified.

Returns

[5] The **qsort** function returns no value.

7.12.6 Integer arithmetic functions

7.12.6.1 The abs function

Synopsis

[1]

```
#include <stdlib.h>
int abs(int j);
```

Description

[2] The **abs** function computes the absolute value of an integer **j**. If the result cannot be represented, the behavior is undefined.[172]

Returns

172. The absolute value of the most negative number cannot be represented in two's complement.

[3] The **abs** function returns the absolute value.

7.12.6.2 The div function

Synopsis

[1]

```
#include <stdlib.h>
div_t div(int numer, int denom);
```

Description

[2] The **div** function computes the quotient and remainder of the division of the numerator **numer** by the denominator **denom**. The returned quotient is the algrebraic quotient with any fractional part discarded. If the result cannot be represented, the behavior is undefined; otherwise, **quot * denom + rem** shall equal **numer**.

Returns

[3] The **div** function returns a structure of type **div_t**, comprising both the quotient and the remainder. The structure shall contain the following members, in either order:

```
int quot;    /* quotient */
int rem;     /* remainder */
```

7.12.6.3 The labs function

Synopsis

[1]

```
#include <stdlib.h>
long int labs(long int j);
```

Description

[2] The **labs** function is equivalent to the **abs** function, except that the argument and the returned value each have type **long int**.

7.12.6.4 The llabs function

Synopsis

[1]

```
#include <stdlib.h>
long long int llabs(long long int j);
```

Description

[2] The **llabs** function is equivalent to the **abs** function, except that the argument and the returned value each have type **long long int**.

7.12.6.5 The `ldiv` function

Synopsis

[1]

```
#include <stdlib.h>
ldiv_t ldiv(long int numer, long int denom);
```

Description

[2] The **`ldiv`** function is equivalent to the **`div`** function, except that the arguments and the members of the returned structure (which has type **`ldiv_t`**) all have type **`long int`**.

7.12.6.6 The `lldiv` function

Synopsis

[1]

```
#include <stdlib.h>
lldiv_t lldiv(long long int numer,
     long long int denom);
```

Description

[2] The **`lldiv`** function is equivalent to the **`div`** function, except that the arguments and the members of the returned structure (which has type **`lldiv_t`**) all have type **`long long int`**.

7.12.7 Multibyte character functions

[1] The behavior of the multibyte character functions is affected by the **`LC_CTYPE`** category of the current locale. For a state-dependent encoding, each function is placed into its initial state by a call for which its character pointer argument, **`s`**, is a null pointer. Subsequent calls with **`s`** as other than a null pointer cause the internal state of the function to be altered as necessary. A call with **`s`** as a null pointer causes these functions to return a nonzero value if encodings have state dependency, and zero otherwise.[173] Changing the **`LC_CTYPE`** category causes the shift state of these functions to be indeterminate.

173. If the locale employs special bytes to change the shift state, these bytes do not produce separate wide character codes, but are grouped with an adjacent multibyte character.

7.12.7.1 The `mblen` function

Synopsis

[1]

```
#include <stdlib.h>
int mblen(const char *s, size_t n);
```

Description

[2] If **s** is not a null pointer, the **mblen** function determines the number of bytes contained in the multibyte character pointed to by **s**. Except that the shift state of the **mbtowc** function is not affected, it is equivalent to

```
mbtowc((wchar_t *)0, s, n);
```

[3] The implementation shall behave as if no library function calls the **mblen** function.

Returns

[4] If **s** is a null pointer, the **mblen** function returns a nonzero or zero value, if multibyte character encodings, respectively, do or do not have state-dependent encodings. If **s** is not a null pointer, the **mblen** function either returns 0 (if **s** points to the null character), or returns the number of bytes that are contained in the multibyte character (if the next **n** or fewer bytes form a valid multibyte character), or returns −1 (if they do not form a valid multibyte character).

Forward references: the **mbtowc** function (7.12.7.2).

7.12.7.2 The `mbtowc` function

Synopsis

[1]

```
#include <stdlib.h>
int mbtowc(wchar_t * restrict pwc,
     const char * restrict s,
     size_t n);
```

Description

[2] If **s** is not a null pointer, the **mbtowc** function determines the number of bytes that are contained in the multibyte character pointed to by **s**. It then determines the code for the value of type **wchar_t** that corresponds to that multibyte character. (The value of the code corresponding to the null character is zero.) If the multibyte character is valid and **pwc** is not a null pointer, the **mbtowc** function stores the code in the object pointed to by **pwc**. At most **n** bytes of the array pointed to by **s** will be examined.

[3] The implementation shall behave as if no library function calls the **mbtowc** function.

Returns

If **`s`** is a null pointer, the **`mbtowc`** function returns a nonzero or zero value, if multibyte character encodings, respectively, do or do not have state-dependent encodings. If **`s`** is not a null pointer, the **`mbtowc`** function either returns 0 (if **`s`** points to the null character), or returns the number of bytes that are contained in the converted multibyte character (if the next **`n`** or fewer bytes form a valid multibyte character), or returns −1 (if they do not form a valid multibyte character).

[4] In no case will the value returned be greater than **`n`** or the value of the **`MB_CUR_MAX`** macro.

7.12.7.3 The `wctomb` function

Synopsis

[1]

```
#include <stdlib.h>
int wctomb(char *s, wchar_t wchar);
```

Description

[2] The **`wctomb`** function determines the number of bytes needed to represent the multibyte character corresponding to the code whose value is **`wchar`** (including any change in shift state). It stores the multibyte character representation in the array object pointed to by **`s`** (if **`s`** is not a null pointer). At most **`MB_CUR_MAX`** characters are stored. If the value of **`wchar`** is zero, the **`wctomb`** function is left in the initial shift state.

[3] The implementation shall behave as if no library function calls the **`wctomb`** function.

Returns

[4] If **`s`** is a null pointer, the **`wctomb`** function returns a nonzero or zero value, if multibyte character encodings, respectively, do or do not have state-dependent encodings. If **`s`** is not a null pointer, the **`wctomb`** function returns −1 if the value of **`wchar`** does not correspond to a valid multibyte character, or returns the number of bytes that are contained in the multibyte character corresponding to the value of **`wchar`**.

[5] In no case will the value returned be greater than the value of the **`MB_CUR_MAX`** macro.

7.12.8 Multibyte string functions

[1] The behavior of the multibyte string functions is affected by the **`LC_CTYPE`** category of the current locale.

7.12.8.1 The `mbstowcs` function

Synopsis

[1]

```
#include <stdlib.h>
size_t mbstowcs(wchar_t * restrict pwcs,
     const char * restrict s,
     size_t n);
```

Description

[2] The **`mbstowcs`** function converts a sequence of multibyte characters that begins in the initial shift state from the array pointed to by **`s`** into a sequence of corresponding codes and stores not more than **`n`** codes into the array pointed to by **`pwcs`**. No multibyte characters that follow a null character (which is converted into a code with value zero) will be examined or converted. Each multibyte character is converted as if by a call to the **`mbtowc`** function, except that the shift state of the **`mbtowc`** function is not affected.

[3] No more than **`n`** elements will be modified in the array pointed to by **`pwcs`**. If copying takes place between objects that overlap, the behavior is undefined.

Returns

[4] If an invalid multibyte character is encountered, the **`mbstowcs`** function returns **`(size_t)-1`**. Otherwise, the **`mbstowcs`** function returns the number of array elements modified, not including a terminating zero code, if any.[174]

7.12.8.2 The `wcstombs` function

Synopsis

[1]

```
#include <stdlib.h>
size_t wcstombs(char * restrict s,
     const wchar_t * restrict pwcs,
     size_t n);
```

Description

174. The array will not be null- or zero-terminated if the value returned is **`n`**.

[2] The **`wcstombs`** function converts a sequence of codes that correspond to multibyte characters from the array pointed to by **`pwcs`** into a sequence of multibyte characters that begins in the initial shift state and stores these multibyte characters into the array pointed to by **`s`**, stopping if a multibyte character would exceed the limit of **`n`** total bytes or if a null character is stored. Each code is converted as if by a call to the **`wctomb`** function, except that the shift state of the **`wctomb`** function is not affected.

[3] No more than **`n`** bytes will be modified in the array pointed to by **`s`**. If copying takes place between objects that overlap, the behavior is undefined.

Returns

[4] If a code is encountered that does not correspond to a valid multibyte character, the **`wcstombs`** function returns **`(size_t)-1`**. Otherwise, the **`wcstombs`** function returns the number of bytes modified, not including a terminating null character, if any.[174]

7.13 String handling `<string.h>`

7.13.1 String function conventions

[1] The header **`<string.h>`** declares one type and several functions, and defines one macro useful for manipulating arrays of character type and other objects treated as arrays of character type.[175] The type is **`size_t`** and the macro is **`NULL`** (both described in 7.1.6). Various methods are used for determining the lengths of the arrays, but in all cases a **`char *`** or **`void *`** argument points to the initial (lowest addressed) character of the array. If an array is accessed beyond the end of an object, the behavior is undefined.

[2] Where an argument declared as **`size_t n`** specifies the length of the array for a function, **`n`** can have the value zero on a call to that function. Unless explicitly stated otherwise in the description of a particular function in this subclause, pointer arguments on such a call must still have valid values, as described in subclause 7.1.7. On such a call, a function that locates a character finds no occurrence, a function that compares two character sequences returns zero, and a function that copies characters copies zero characters. *

7.13.2 Copying functions

7.13.2.1 The `memcpy` function

Synopsis

[1]

```
#include <string.h>
void *memcpy(void * restrict s1,
     const void * restrict s2,
     size_t n);
```

Description

[2] The **`memcpy`** function copies **`n`** characters from the object pointed to by **`s2`** into the object pointed to by **`s1`**. If copying takes place between objects that overlap, the behavior is undefined.

Returns

[3] The **`memcpy`** function returns the value of **`s1`**.

---

175. See ‘‘future library directions’’ (7.18.8).

7.13.2.2 The **memmove** function

Synopsis

[1]

```
#include <string.h>
void *memmove(void *s1, const void *s2, size_t n);
```

Description

[2] The **memmove** function copies **n** characters from the object pointed to by **s2** into the object pointed to by **s1**. Copying takes place as if the **n** characters from the object pointed to by **s2** are first copied into a temporary array of **n** characters that does not overlap the objects pointed to by **s1** and **s2**, and then the **n** characters from the temporary array are copied into the object pointed to by **s1**.

Returns

[3] The **memmove** function returns the value of **s1**.

7.13.2.3 The **strcpy** function

Synopsis

[1]

```
#include <string.h>
char *strcpy(char * restrict s1,
     const char * restrict s2);
```

Description

[2] The **strcpy** function copies the string pointed to by **s2** (including the terminating null character) into the array pointed to by **s1**. If copying takes place between objects that overlap, the behavior is undefined.

Returns

[3] The **strcpy** function returns the value of **s1**.

7.13.2.4 The **strncpy** function

Synopsis

[1]

```
#include <string.h>
char *strncpy(char * restrict s1,
     const char * restrict s2,
     size_t n);
```

Description

[2] The **strncpy** function copies not more than **n** characters (characters that follow a null character are not copied) from the array pointed to by **s2** to the array pointed to by **s1**.[176] If copying takes place between objects that overlap, the behavior is undefined.

[3] If the array pointed to by **s2** is a string that is shorter than **n** characters, null characters are appended to the copy in the array pointed to by **s1**, until **n** characters in all have been written.

Returns

[4] The **strncpy** function returns the value of **s1**.

7.13.3 Concatenation functions

7.13.3.1 The strcat function

Synopsis

[1]

```
#include <string.h>
char *strcat(char * restrict s1,
     const char * restrict s2);
```

Description

[2] The **strcat** function appends a copy of the string pointed to by **s2** (including the terminating null character) to the end of the string pointed to by **s1**. The initial character of **s2** overwrites the null character at the end of **s1**. If copying takes place between objects that overlap, the behavior is undefined.

Returns

[3] The **strcat** function returns the value of **s1**.

7.13.3.2 The strncat function

Synopsis

[1]

```
#include <string.h>
char *strncat(char * restrict s1,
     const char * restrict s2,
     size_t n);
```

Description

[2] The **strncat** function appends not more than **n** characters (a null character and

176. Thus, if there is no null character in the first **n** characters of the array pointed to by **s2**, the result will not be null-terminated.

characters that follow it are not appended) from the array pointed to by **s2** to the end of the string pointed to by **s1**. The initial character of **s2** overwrites the null character at the end of **s1**. A terminating null character is always appended to the result.[177] If copying takes place between objects that overlap, the behavior is undefined.

Returns

[3] The **strncat** function returns the value of **s1**.

Forward references: the **strlen** function (7.13.6.3).

7.13.4 Comparison functions

[1] The sign of a nonzero value returned by the comparison functions **memcmp**, **strcmp**, and **strncmp** is determined by the sign of the difference between the values of the first pair of characters (both interpreted as **unsigned char**) that differ in the objects being compared.

7.13.4.1 The memcmp function

Synopsis

[1]

```
#include <string.h>
int memcmp(const void *s1, const void *s2, size_t n);
```

Description

[2] The **memcmp** function compares the first **n** characters of the object pointed to by **s1** to the first **n** characters of the object pointed to by **s2**.[178]

Returns

[3] The **memcmp** function returns an integer greater than, equal to, or less than zero, accordingly as the object pointed to by **s1** is greater than, equal to, or less than the object pointed to by **s2**.

177. Thus, the maximum number of characters that can end up in the array pointed to by **s1** is **strlen(s1)+n+1**.

178. The contents of ‘‘holes’’ used as padding for purposes of alignment within structure objects are indeterminate. Strings shorter than their allocated space and unions may also cause problems in comparison.

7.13.4.2 The `strcmp` function

Synopsis

[1]

```
#include <string.h>
int strcmp(const char *s1, const char *s2);
```

Description

[2] The **strcmp** function compares the string pointed to by **s1** to the string pointed to by **s2**.

Returns

[3] The **strcmp** function returns an integer greater than, equal to, or less than zero, accordingly as the string pointed to by **s1** is greater than, equal to, or less than the string pointed to by **s2**.

7.13.4.3 The `strcoll` function

Synopsis

[1]

```
#include <string.h>
int strcoll(const char *s1, const char *s2);
```

Description

The **strcoll** function compares the string pointed to by **s1** to the string pointed to by **s2**, both interpreted as appropriate to the **LC_COLLATE** category of the current locale.

Returns

[2] The **strcoll** function returns an integer greater than, equal to, or less than zero, accordingly as the string pointed to by **s1** is greater than, equal to, or less than the string pointed to by **s2** when both are interpreted as appropriate to the current locale.

7.13.4.4 The `strncmp` function

Synopsis

[1]

```
#include <string.h>
int strncmp(const char *s1, const char *s2, size_t n);
```

Description

[2] The **strncmp** function compares not more than **n** characters (characters that follow a null character are not compared) from the array pointed to by **s1** to the array pointed to by **s2**.

Returns

[3] The **strncmp** function returns an integer greater than, equal to, or less than zero, accordingly as the possibly null-terminated array pointed to by **s1** is greater than, equal to, or less than the possibly null-terminated array pointed to by **s2**.

7.13.4.5 The strxfrm function

Synopsis

[1]

```
#include <string.h>
size_t strxfrm(char * restrict s1,
     const char * restrict s2,
     size_t n);
```

Description

[2] The **strxfrm** function transforms the string pointed to by **s2** and places the resulting string into the array pointed to by **s1**. The transformation is such that if the **strcmp** function is applied to two transformed strings, it returns a value greater than, equal to, or less than zero, corresponding to the result of the **strcoll** function applied to the same two original strings. No more than **n** characters are placed into the resulting array pointed to by **s1**, including the terminating null character. If **n** is zero, **s1** is permitted to be a null pointer. If copying takes place between objects that overlap, the behavior is undefined.

Returns

[3] The **strxfrm** function returns the length of the transformed string (not including the terminating null character). If the value returned is **n** or more, the contents of the array pointed to by **s1** are indeterminate.

Example

[4] The value of the following expression is the size of the array needed to hold the transformation of the string pointed to by **s**.

```
1 + strxfrm(NULL, s, 0)
```

7.13.5 Search functions

7.13.5.1 The memchr function

Synopsis

[1]

```
#include <string.h>
void *memchr(const void *s, int c, size_t n);
```

Description

[2] The **memchr** function locates the first occurrence of **c** (converted to an

unsigned char) in the initial **n** characters (each interpreted as **unsigned char**) of the object pointed to by **s**.

Returns

[3] The **memchr** function returns a pointer to the located character, or a null pointer if the character does not occur in the object.

7.13.5.2 The strchr function

Synopsis

[1]

```
#include <string.h>
char *strchr(const char *s, int c);
```

Description

[2] The **strchr** function locates the first occurrence of **c** (converted to a **char**) in the string pointed to by **s**. The terminating null character is considered to be part of the string.

Returns

[3] The **strchr** function returns a pointer to the located character, or a null pointer if the character does not occur in the string.

7.13.5.3 The strcspn function

Synopsis

[1]

```
#include <string.h>
size_t strcspn(const char *s1, const char *s2);
```

Description

[2] The **strcspn** function computes the length of the maximum initial segment of the string pointed to by **s1** which consists entirely of characters *not* from the string pointed to by **s2**.

Returns

[3] The **strcspn** function returns the length of the segment.

7.13.5.4 The strpbrk function

Synopsis

[1]

```
#include <string.h>
char *strpbrk(const char *s1, const char *s2);
```

Description

[2] The **`strpbrk`** function locates the first occurrence in the string pointed to by **`s1`** of any character from the string pointed to by **`s2`**.

Returns

[3] The **`strpbrk`** function returns a pointer to the character, or a null pointer if no character from **`s2`** occurs in **`s1`**.

7.13.5.5 The `strrchr` function

Synopsis

[1]

```
#include <string.h>
char *strrchr(const char *s, int c);
```

Description

[2] The **`strrchr`** function locates the last occurrence of **`c`** (converted to a **`char`**) in the string pointed to by **`s`**. The terminating null character is considered to be part of the string.

Returns

[3] The **`strrchr`** function returns a pointer to the character, or a null pointer if **`c`** does not occur in the string.

7.13.5.6 The `strspn` function

Synopsis

[1]

```
#include <string.h>
size_t strspn(const char *s1, const char *s2);
```

Description

[2] The **`strspn`** function computes the length of the maximum initial segment of the string pointed to by **`s1`** which consists entirely of characters from the string pointed to by **`s2`**.

Returns

[3] The **`strspn`** function returns the length of the segment.

7.13.5.7 The `strstr` function

Synopsis

[1]

```
#include <string.h>
char *strstr(const char *s1, const char *s2);
```

Description

[2] The **strstr** function locates the first occurrence in the string pointed to by **s1** of the sequence of characters (excluding the terminating null character) in the string pointed to by **s2**

Returns

[3] The **strstr** function returns a pointer to the located string, or a null pointer if the string is not found. If **s2** points to a string with zero length, the function returns **s1**.

7.13.5.8 The strtok function

Synopsis

[1]

```
#include <string.h>
char *strtok(char * restrict s1,
     const char * restrict s2);
```

Description

[2] A sequence of calls to the **strtok** function breaks the string pointed to by **s1** into a sequence of tokens, each of which is delimited by a character from the string pointed to by **s2**. The first call in the sequence has **s1** as its first argument, and is followed by calls with a null pointer as their first argument. The separator string pointed to by **s2** may be different from call to call.

[3] The first call in the sequence searches the string pointed to by **s1** for the first character that is *not* contained in the current separator string pointed to by **s2**. If no such character is found, then there are no tokens in the string pointed to by **s1** and the **strtok** function returns a null pointer. If such a character is found, it is the start of the first token.

[4] The **strtok** function then searches from there for a character that *is* contained in the current separator string. If no such character is found, the current token extends to the end of the string pointed to by **s1**, and subsequent searches for a token will return a null pointer. If such a character is found, it is overwritten by a null character, which terminates the current token. The **strtok** function saves a pointer to the following character, from which the next search for a token will start.

[5] Each subsequent call, with a null pointer as the value of the first argument, starts searching from the saved pointer and behaves as described above.

[6] The implementation shall behave as if no library function calls the **strtok** function.

Returns

[7] The **strtok** function returns a pointer to the first character of a token, or a null pointer if there is no token.

Example

```
#include <string.h>
static char str[] = "?a???b,,,#c";
char *t;

t = strtok(str, "?");     /* t points to the token "a" */
t = strtok(NULL, ",");    /* t points to the token "??b" */
t = strtok(NULL, "#,");   /* t points to the token "c" */
t = strtok(NULL, "?");    /* t is a null pointer */
```

7.13.6 Miscellaneous functions

7.13.6.1 The `memset` function

Synopsis

[1]

```
#include <string.h>
void *memset(void *s, int c, size_t n);
```

Description

[2] The **`memset`** function copies the value of **`c`** (converted to an **`unsigned char`**) into each of the first **`n`** characters of the object pointed to by **`s`**.

Returns

[3] The **`memset`** function returns the value of **`s`**.

7.13.6.2 The `strerror` function

Synopsis

[1]

```
#include <string.h>
char *strerror(int errnum);
```

Description

[2] The **`strerror`** function maps the error number in **`errnum`** to an error message string.

[3] The implementation shall behave as if no library function calls the **`strerror`** function.

Returns

[4] The **`strerror`** function returns a pointer to the string, the contents of which are locale-specific. The array pointed to shall not be modified by the program, but may be overwritten by a subsequent call to the **`strerror`** function.

7.13.6.3 The `strlen` function

Synopsis

[1]

```
#include <string.h>
size_t strlen(const char *s);
```

Description

[2] The **strlen** function computes the length of the string pointed to by **s**.

Returns

[3] The **strlen** function returns the number of characters that precede the terminating null character.

7.14 Date and time `<time.h>`

7.14.1 Components of time

[1] The header **`<time.h>`** defines two macros, and declares four types and several functions for manipulating time. Many functions deal with a *calendar time* that represents the current date (according to the Gregorian calendar) and time. Some functions deal with *local time*, which is the calendar time expressed for some specific time zone, and with *Daylight Saving Time*, which is a temporary change in the algorithm for determining local time. The local time zone and Daylight Saving Time are implementation-defined.

[2] The macros defined are **`NULL`** (described in 7.1.6); and

```
CLOCKS_PER_SEC
```

which is the number per second of the value returned by the **`clock`** function.

[3] The types declared are **`size_t`** (described in 7.1.6);

```
clock_t
```

and

```
time_t
```

which are arithmetic types capable of representing times; and

```
struct tm
```

which holds the components of a calendar time, called the *broken-down time*. The structure shall contain at least the following members, in any order. The semantics of the members and their normal ranges are expressed in the comments.[179]

```
int tm_sec;   /* seconds after the minute — [0, 61] */
int tm_min;   /* minutes after the hour — [0, 59] */
int tm_hour;  /* hours since midnight — [0, 23] */
int tm_mday;  /* day of the month — [1, 31] */
int tm_mon;   /* months since January — [0, 11] */
int tm_year;  /* years since 1900 */
int tm_wday;  /* days since Sunday — [0, 6] */
int tm_yday;  /* days since January 1 — [0, 365] */
int tm_isdst; /* Daylight Saving Time flag */
```

The value of **`tm_isdst`** is positive if Daylight Saving Time is in effect, zero if Daylight Saving Time is not in effect, and negative if the information is not available.

---

179. The range [0, 61] for **`tm_sec`** allows for as many as two leap seconds.

7.14.2 Time manipulation functions

7.14.2.1 The `clock` function

Synopsis

[1]

```
#include <time.h>
clock_t clock(void);
```

Description

[2] The **`clock`** function determines the processor time used.

Returns

[3] The **`clock`** function returns the implementation's best approximation to the processor time used by the program since the beginning of an implementation-defined era related only to the program invocation. To determine the time in seconds, the value returned by the **`clock`** function should be divided by the value of the macro **`CLOCKS_PER_SEC`**. If the processor time used is not available or its value cannot be represented, the function returns the value **`(clock_t)-1`**.[180]

7.14.2.2 The `difftime` function

Synopsis

[1]

```
#include <time.h>
double difftime(time_t time1, time_t time0);
```

Description

[2] The **`difftime`** function computes the difference between two calendar times: **`time1 - time0`**.

Returns

[3] The **`difftime`** function returns the difference expressed in seconds as a **`double`**.

180. In order to measure the time spent in a program, the **`clock`** function should be called at the start of the program and its return value subtracted from the value returned by subsequent calls.

7.14.2.3 The mktime function

Synopsis

[1]

```
#include <time.h>
time_t mktime(struct tm *timeptr);
```

Description

[2] The **mktime** function converts the broken-down time, expressed as local time, in the structure pointed to by **timeptr** into a calendar time value with the same encoding as that of the values returned by the **time** function. The original values of the **tm_wday** and **tm_yday** components of the structure are ignored, and the original values of the other components are not restricted to the ranges indicated above.[181] On successful completion, the values of the **tm_wday** and **tm_yday** components of the structure are set appropriately, and the other components are set to represent the specified calendar time, but with their values forced to the ranges indicated above; the final value of **tm_mday** is not set until **tm_mon** and **tm_year** are determined.

Returns

[3] The **mktime** function returns the specified calendar time encoded as a value of type **time_t**. If the calendar time cannot be represented, the function returns the value **(time_t)-1**.

Example

[4] What day of the week is July 4, 2001?

[5]

```
#include <stdio.h>
#include <time.h>
static const char *const wday[] = {
     "Sunday", "Monday", "Tuesday", "Wednesday",
     "Thursday", "Friday", "Saturday", "-unknown-"
};
struct tm time_str;
/*...*/
```

181. Thus, a positive or zero value for **tm_isdst** causes the **mktime** function to presume initially that Daylight Saving Time, respectively, is or is not in effect for the specified time. A negative value causes it to attempt to determine whether Daylight Saving Time is in effect for the specified time.

```
time_str.tm_year   = 2001 - 1900;
time_str.tm_mon    = 7 - 1;
time_str.tm_mday   = 4;
time_str.tm_hour   = 0;
time_str.tm_min    = 0;
time_str.tm_sec    = 1;
time_str.tm_isdst  = -1;
if (mktime(&time_str) == (time_t)-1)
     time_str.tm_wday = 7;
printf("%s\n", wday[time_str.tm_wday]);
```
*

7.14.2.4 The `time` function

Synopsis

[1]

```
#include <time.h>
time_t time(time_t *timer);
```

Description

[2] The **`time`** function determines the current calendar time. The encoding of the value is unspecified.

Returns

[3] The **`time`** function returns the implementation's best approximation to the current calendar time. The value **`(time_t)-1`** is returned if the calendar time is not available. If **`timer`** is not a null pointer, the return value is also assigned to the object it points to.

7.14.3 Time conversion functions

[1] Except for the **`strftime`** function, these functions return values in one of two static objects: a broken-down time structure and an array of **`char`**. Execution of any of the functions may overwrite the information returned in either of these objects by any of the other functions. The implementation shall behave as if no other library functions call these functions.

7.14.3.1 The `asctime` function

Synopsis

[1]

```
#include <time.h>
char *asctime(const struct tm *timeptr);
```

Description

[2] The **`asctime`** function converts the broken-down time in the structure pointed to by **`timeptr`** into a string in the form

```
Sun Sep 16 01:03:52 1973\n\0
```

using the equivalent of the following algorithm.

```
char *asctime(const struct tm *timeptr)
{
     static const char wday_name[7][3] = {
          "Sun", "Mon", "Tue", "Wed", "Thu", "Fri", "Sat"
     };
     static const char mon_name[12][3] = {
          "Jan", "Feb", "Mar", "Apr", "May", "Jun",
          "Jul", "Aug", "Sep", "Oct", "Nov", "Dec"
     };
     static char result[26];

     sprintf(result, "%.3s %.3s%3d %.2d:%.2d:%.2d %d\n",
          wday_name[timeptr->tm_wday],
          mon_name[timeptr->tm_mon],
          timeptr->tm_mday, timeptr->tm_hour,
          timeptr->tm_min, timeptr->tm_sec,
          1900 + timeptr->tm_year);
     return result;
}
```

Returns

[3] The **asctime** function returns a pointer to the string.

7.14.3.2 The ctime function

Synopsis

[1]

```
#include <time.h>
char *ctime(const time_t *timer);
```

Description

[2] The **ctime** function converts the calendar time pointed to by **timer** to local time in the form of a string. It is equivalent to

```
asctime(localtime(timer))
```

Returns

[3] The **ctime** function returns the pointer returned by the **asctime** function with that broken-down time as argument.

Forward references: the **localtime** function (7.14.3.4).

7.14.3.3 The `gmtime` function

Synopsis

[1]

```
#include <time.h>
struct tm *gmtime(const time_t *timer);
```

Description

[2] The **gmtime** function converts the calendar time pointed to by **timer** into a broken-down time, expressed as Coordinated Universal Time (UTC).

Returns

[3] The **gmtime** function returns a pointer to that object, or a null pointer if UTC is not available.

7.14.3.4 The `localtime` function

Synopsis

[1]

```
#include <time.h>
struct tm *localtime(const time_t *timer);
```

Description

[2] The **localtime** function converts the calendar time pointed to by **timer** into a broken-down time, expressed as local time.

Returns

[3] The **localtime** function returns a pointer to that object.

7.14.3.5 The `strftime` function

Synopsis

[1]

```
#include <time.h>
size_t strftime(char * restrict s,
     size_t maxsize,
     const char * restrict format,
     const struct tm * restrict timeptr);
```

Description

[2] The **strftime** function places characters into the array pointed to by **s** as controlled by the string pointed to by **format**. The format shall be a multibyte character sequence, beginning and ending in its initial shift state. The **format** string consists of zero or more conversion specifiers and ordinary multibyte characters. A conversion specifier consists of a **%** character followed by a character that determines the behavior of the conversion specifier. All ordinary multibyte characters (including the terminating null character) are copied unchanged into the array. If copying takes place between objects that overlap, the behavior is undefined. No more than **maxsize** characters are placed into the array. Each conversion specifier is replaced by appropriate characters as described in the following list. The appropriate characters are determined by the **LC_TIME** category of the current locale and by the values contained in the structure pointed to by **timeptr**.

[3]

- **%a** is replaced by the locale's abbreviated weekday name.
- **%A** is replaced by the locale's full weekday name.
- **%b** is replaced by the locale's abbreviated month name.
- **%B** is replaced by the locale's full month name.
- **%c** is replaced by the locale's appropriate date and time representation.
- **%d** is replaced by the day of the month as a decimal number (**01**-**31**).
- **%H** is replaced by the hour (24-hour clock) as a decimal number (**00**-**23**).
- **%I** is replaced by the hour (12-hour clock) as a decimal number (**01**-**12**).
- **%j** is replaced by the day of the year as a decimal number (**001**-**366**).
- **%m** is replaced by the month as a decimal number (**01**-**12**).
- **%M** is replaced by the minute as a decimal number (**00**-**59**).
- **%p** is replaced by the locale's equivalent of the AM/PM designations associated with a 12-hour clock.
- **%S** is replaced by the second as a decimal number (**00**-**61**).
- **%U** is replaced by the week number of the year (the first Sunday as the first day of week 1) as a decimal number (**00**-**53**).
- **%w** is replaced by the weekday as a decimal number (**0**-**6**), where Sunday is **0**.
- **%W** is replaced by the week number of the year (the first Monday as the first day of week 1) as a decimal number (**00**-**53**).
- **%x** is replaced by the locale's appropriate date representation.
- **%X** is replaced by the locale's appropriate time representation.
- **%y** is replaced by the year without century as a decimal number (**00**-**99**).
- **%Y** is replaced by the year with century as a decimal number.
- **%Z** is replaced by the time zone name or abbreviation, or by no characters if no time zone is determinable.
- **%%** is replaced by **%**.

[4] If a conversion specifier is not one of the above, the behavior is undefined.

Returns

[5] If the total number of resulting characters including the terminating null character is not more than **maxsize**, the **strftime** function returns the number of characters placed into the array pointed to by **s** not including the terminating null character. Otherwise, zero is returned and the contents of the array are indeterminate.

7.15 Alternative spellings **`<iso646.h>`**

[1] The header **`<iso646.h>`** defines the following eleven macros (on the left) that expand to the corresponding tokens (on the right):

```
and       &&
and_eq    &=
bitand    &
bitor     |
compl     ~
not       !
not_eq    !=
or        ||
or_eq     |=
xor       ^
xor_eq    ^=
```

7.16 Wide-character classification and mapping utilities

<wctype.h>

7.16.1 Introduction

[1] The header **<wctype.h>** declares three data types, one macro, and many functions.[182]

[2] The types declared are

wint_t

[3] which is an integral type unchanged by default argument promotions that can hold any value corresponding to members of the extended character set, as well as at least one value that does not correspond to any member of the extended character set. (See **WEOF** below.)[183]

wctrans_t

[4] which is a scalar type that can hold values which represent locale-specific character mappings, and

wctype_t

[5] which is a scalar type that can hold values which represent locale-specific character classifications.

[6] The macro defined is

WEOF

[7] which expands to a constant expression of type **wint_t** whose value does not correspond to any member of the extended character set.[184] It is accepted (and returned) by several functions in this subclause to indicate *end-of-file*, that is, no more input from a stream. It is also used as a wide-character value that does not correspond to any member of the extended character set.

[8] The functions declared are grouped as follows:

- Functions that provide wide-character classification;
- Extensible functions that provide wide-character classification;
- Functions that provide wide-character case mapping;

---

182. See ‘‘future library directions’’ (7.18).

183. **wchar_t** and **wint_t** can be the same integral type.

184. The value of the macro **WEOF** may differ from that of **EOF** and need not be negative.

- Extensible functions that provide wide-character mapping.

[9] For all functions described in this subclause that accept an argument of type **`wint_t`**, the value shall be representable as a **`wchar_t`** or shall equal the value of the macro **`WEOF`**. If this argument has any other value, the behavior is undefined.

[10] The behavior of these functions is affected by the **`LC_CTYPE`** category of the current locale.

7.16.2 Wide-character classification utilities

[1] The header **`<wctype.h>`** declares several functions useful for classifying wide characters.

[2] The term *printing wide character* refers to a member of a locale-specific set of wide characters, each of which occupies at least one printing position on a display device. The term *control wide character* refers to a member of a locale-specific set of wide characters that are not printing wide characters.

7.16.2.1 Wide-character classification functions

[1] The functions in this subclause return nonzero (true) if and only if the value of the argument **`wc`** conforms to that in the description of the function.

[2] Except for the **`iswgraph`** and **`iswpunct`** functions with respect to printing white-space wide characters other than **`L' '`**, each of the following eleven functions returns true for each wide character that corresponds (as if by a call to the **`wctob`** function) to a character (byte) for which the respectively matching character testing function from subclause 7.3.1 returns true.[185]

[3] Forward References: the **`wctob`** function (7.17.6.1.2).

7.16.2.1.1 The `iswalnum` function

Synopsis

[1]

```
#include <wctype.h>
int iswalnum(wint_t wc);
```

Description

[2] The **`iswalnum`** function tests for any wide character for which **`iswalpha`** or **`iswdigit`** is true.

---

185. For example, if the expression **`isalpha(wctob(wc))`** evaluates to true, then the call **`iswalpha(wc)`** must also return true. But, if the expression **`isgraph(wctob(wc))`** evaluates to true (which cannot occur for **`wc == L' '`** of course), then either **`iswgraph(wc)`** or **`iswprint(wc) && iswspace(wc)`** must be true, but not both.

7.16.2.1.2 The `iswalpha` function

Synopsis

[1]

```
#include <wctype.h>
int iswalpha(wint_t wc);
```

Description

[2] The **`iswalpha`** function tests for any wide character for which **`iswupper`** or **`iswlower`** is true, or any wide character that is one of a locale-specific set of wide characters for which none of **`iswcntrl`**, **`iswdigit`**, **`iswpunct`**, or **`iswspace`** is true.

7.16.2.1.3 The `iswcntrl` function

Synopsis

[1]

```
#include <wctype.h>
int iswcntrl(wint_t wc);
```

Description

[2] The **`iswcntrl`** function tests for any control wide character.

7.16.2.1.4 The `iswdigit` function

Synopsis

[1]

```
#include <wctype.h>
int iswdigit(wint_t wc);
```

Description

[2] The **`iswdigit`** function tests for any wide character that corresponds to a decimal-digit character (as defined in subclause 5.2.1).

7.16.2.1.5 The `iswgraph` function

Synopsis

[1]

```
#include <wctype.h>
int iswgraph(wint_t wc);
```

Description

[2] The **`iswgraph`** function tests for any wide character for which **`iswprint`** is true and **`iswspace`** is false.[186]

7.16.2.1.6 The `iswlower` function

Synopsis

[1]

```
#include <wctype.h>
int iswlower(wint_t wc);
```

Description

[2] The **iswlower** function tests for any wide character that corresponds to a lowercase letter or is one of a locale-specific set of wide characters for which none of **iswcntrl**, **iswdigit**, **iswpunct**, or **iswspace** is true.

7.16.2.1.7 The `iswprint` function

Synopsis

[1]

```
#include <wctype.h>
int iswprint(wint_t wc);
```

Description

[2] The **iswprint** function tests for any printing wide character.

7.16.2.1.8 The `iswpunct` function

Synopsis

[1]

```
#include <wctype.h>
int iswpunct(wint_t wc);
```

Description

[2] The **iswpunct** function tests for any printing wide character that is one of a locale-specific set of wide characters for which neither **iswspace** nor **iswalnum** is true.

7.16.2.1.9 The `iswspace` function

Synopsis

[1]

---

186. Note that the behavior of the **iswgraph** and **iswpunct** functions may differ from their matching functions in subclause 7.3.1 with respect to printing white space basic execution characters other than **' '**.

```
#include <wctype.h>
int iswspace(wint_t wc);
```

Description

[2] The **iswspace** function tests for any wide character that corresponds to a locale-specific set of wide characters for which none of **iswalnum**, **iswgraph**, or **iswpunct** is true.

7.16.2.1.10 The iswupper function

Synopsis

[1]

```
#include <wctype.h>
int iswupper(wint_t wc);
```

Description

[2] The **iswupper** function tests for any wide character that corresponds to an uppercase letter or is one of a locale-specific set of wide characters for which none of **iswcntrl**, **iswdigit**, **iswpunct**, or **iswspace** is true.

7.16.2.1.11 The iswxdigit function

Synopsis

[1]

```
#include <wctype.h>
int iswxdigit(wint_t wc);
```

Description

[2] The **iswxdigit** function tests for any wide character that corresponds to a hexadecimal-digit character (as defined in subclause 6.1.3.2).

7.16.2.2 Extensible wide-character classification functions

[1] The functions **wctype** and **iswctype** provide extensible wide-character classification as well as testing equivalent to that performed by the functions described in the previous subclause (4.5.2.1).

7.16.2.2.1 The wctype function

Synopsis

[1]

```
#include <wctype.h>
wctype_t wctype(const char *property);
```

Description

[2] The **wctype** function constructs a value with type **wctype_t** that describes a class of wide characters identified by the string argument **property**.

[3] The eleven strings listed in the description of the **iswctype** function shall be valid in all locales as **property** arguments to the **wctype** function.

Returns

[4] If **property** identifies a valid class of wide characters according to the **LC_CTYPE** category of the current locale, the **wctype** function returns a nonzero value that is valid as the second argument to the **iswctype** function; otherwise, it returns zero.

7.16.2.2.2 The iswctype function

Synopsis

[1]

```
#include <wctype.h>
int iswctype(wint_t wc, wctype_t desc);
```

Description

[2] The **iswctype** function determines whether the wide character **wc** has the property described by **desc**. The current setting of the **LC_CTYPE** category shall be the same as during the call to **wctype** that returned the value **desc**.

[3] Each of the following eleven expressions has a truth-value equivalent to the call to the wide-character testing function (4.5.2.1) in the comment that follows the expression:

```
iswctype(wc, wctype("alnum"))    /* iswalnum(wc) */
iswctype(wc, wctype("alpha"))    /* iswalpha(wc) */
iswctype(wc, wctype("cntrl"))    /* iswcntrl(wc) */
iswctype(wc, wctype("digit"))    /* iswdigit(wc) */
iswctype(wc, wctype("graph"))    /* iswgraph(wc) */
iswctype(wc, wctype("lower"))    /* iswlower(wc) */
iswctype(wc, wctype("print"))    /* iswprint(wc) */
iswctype(wc, wctype("punct"))    /* iswpunct(wc) */
iswctype(wc, wctype("space"))    /* iswspace(wc) */
iswctype(wc, wctype("upper"))    /* iswupper(wc) */
iswctype(wc, wctype("xdigit"))   /* iswxdigit(wc) */
```

Returns

[4] The **iswctype** function returns nonzero (true) if and only if the value of the wide character **wc** has the property described by **desc**.

7.16.3 Wide-character mapping utilities

[1] The header **`<wctype.h>`** declares several functions useful for mapping wide characters.

7.16.3.1 Wide-character case-mapping functions

7.16.3.1.1 The `towlower` function

Synopsis

[1]

```
#include <wctype.h>
wint_t towlower(wint_t wc);
```

Description

[2] The **`towlower`** function converts an uppercase letter to the corresponding lowercase letter.

Returns

[3] If the argument is a wide character for which **`iswupper`** is true and there is a corresponding wide character for which **`iswlower`** is true, the **`towlower`** function returns the corresponding wide character; otherwise, the argument is returned unchanged.

7.16.3.1.2 The `towupper` function

Synopsis

[1]

```
#include <wctype.h>
wint_t towupper(wint_t wc);
```

Description

[2] The **`towupper`** function converts a lowercase letter to the corresponding uppercase letter.

Returns

[3] If the argument is a wide character for which **`iswlower`** is true and there is a corresponding wide character for which **`iswupper`** is true, the **`towupper`** function returns the corresponding wide character; otherwise, the argument is returned unchanged.

7.16.3.2 Extensible wide-character mapping functions

[1] The functions **wctrans** and **towctrans** provide extensible wide-character mapping as well as case mapping equivalent to that performed by the functions described in the previous subclause (7.16.3.1).

7.16.3.2.1 The wctrans function

Synopsis

[1]

```
#include <wctype.h>
wctrans_t wctrans(const char *property);
```

Description

[2] The **wctrans** function constructs a value with type **wctrans_t** that describes a mapping between wide characters identified by the string argument **property**.

[3] The two strings listed in the description of the **towctrans** function shall be valid in all locales as **property** arguments to the **wctrans** function.

Returns

[4] If **property** identifies a valid mapping of wide characters according to the **LC_CTYPE** category of the current locale, the **wctrans** function returns a nonzero value that is valid as the second argument to the **towctrans** function; otherwise, it returns zero.

7.16.3.2.2 The towctrans function

Synopsis

[1]

```
#include <wctype.h>
wint_t towctrans(wint_t wc, wctrans_t desc);
```

Description

[2] The **towctrans** function maps the wide character **wc** using the mapping described by **desc**. The current setting of the **LC_CTYPE** category shall be the same as during the call to **wctrans** that returned the value **desc**.

[3] Each of the following two expressions behaves the same as the call to the wide-character case-mapping function (7.16.3.1) in the comment that follows the expression:

```
towctrans(wc, wctrans("tolower"))    /* towlower(wc) */
towctrans(wc, wctrans("toupper"))    /* towupper(wc) */
```

Returns

[4] The **towctrans** function returns the mapped value of **wc** using the mapping described by **desc**.

7.17 Extended multibyte and wide-character utilities `<wchar.h>`

7.17.1 Introduction

[1] The header `<wchar.h>` declares four data types, one tag, four macros, and many functions.[187]

[2] The types declared are `wchar_t` and `size_t` (both described in subclause 7.1.6),

`mbstate_t`

[3] which is an object type other than an array type that can hold the conversion state information necessary to convert between sequences of multibyte characters and wide characters, and

`wint_t`

[4] described in subclause 7.16.1.

[5] The tag `tm` is declared as naming an incomplete structure type, the contents of which are described in subclause 7.13.1.

[6] The macros defined are `NULL` (described in subclause 7.1.6),

`WCHAR_MAX`

[7] which is the maximum value representable by an object of type `wchar_t`,[188]

`WCHAR_MIN`

[8] which is the minimum value representable by an object of type `wchar_t`, and

`WEOF`

[9] described in subclause 7.16.1.

[10] The functions declared are grouped as follows:

- Functions that perform input and output of wide characters, or multibyte characters, or both;
- Functions that provide wide-string numeric conversion;
- Functions that perform general wide-string manipulation;
- A function for wide-string date and time conversion; and

187. See ‘‘future library directions’’ (7.18).

188. The values `WCHAR_MAX` and `WCHAR_MIN` do not necessarily correspond to members of the extended character set.

- Functions that provide extended capabilities for conversion between multibyte and wide-character sequences.

[11] Unless explicitly stated otherwise, if the execution of a function described in this subclause causes copying to take place between objects that overlap, the behavior is undefined.

7.17.2 Formatted wide-character input/output functions

7.17.2.1 The `fwprintf` function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
int fwprintf(FILE * restrict stream,
     const wchar_t * restrict format, ...);
```

Description

[2] The **`fwprintf`** function writes output to the stream pointed to by **`stream`**, under control of the wide string pointed to by **`format`** that specifies how subsequent arguments are converted for output. If there are insufficient arguments for the format, the behavior is undefined. If the format is exhausted while arguments remain, the excess arguments are evaluated (as always) but are otherwise ignored. The **`fwprintf`** function returns when the end of the format string is encountered.

[3] The format is composed of zero or more directives: ordinary wide characters (not **`%`**), and conversion specifications. The processing of conversion specifications is as if they were replaced in the format string by wide-character strings that are each the result of fetching zero or more subsequent arguments and converting them, if applicable, according to the corresponding conversion specifier. The expanded wide-character format string is then written to the output stream.

[4] Each conversion specification is introduced by the wide character **`%`**. After the **`%`**, the following appear in sequence:

- Zero or more *flags* (in any order) that modify the meaning of the conversion specification.
- An optional minimum *field width*. If the converted value has fewer wide characters than the field width, it is padded with spaces (by default) on the left (or right, if the left adjustment flag, described later, has been given) to the field width. The field width takes the form of an asterisk **`*`** (described later) or a decimal integer.[189]

- An optional *precision* that gives the minimum number of digits to appear for the **d**, **i**, **o**, **u**, **x**, and **X** conversions, the number of digits to appear after the decimal-point character for **e**, **E**, and **f** conversions, the maximum number of significant digits for the **g** and **G** conversions, or the maximum number of wide characters to be written from a string in **s** conversion. The precision takes the form of a period (**.**) followed either by an asterisk ***** (described later) or by an optional decimal integer; if only the period is specified, the precision is taken as zero. If a precision appears with any other conversion specifier, the behavior is undefined.

- An optional **l** (ell) specifying that a following **c** conversion specifier applies to a **wint_t** argument; an optional **l** specifying that a following **s** conversion specifier applies to a pointer to a **wchar_t** argument; an optional **h** specifying that a following **d**, **i**, **o**, **u**, **x**, or **X** conversion specifier applies to a **short int** or **unsigned short int** argument (the argument is promoted according to the integral promotions, and its value is converted to **short int** or **unsigned short int** before printing); an optional **h** specifying that a following **n** conversion specifier applies to a pointer to a **short int** argument; an optional **l** specifying that a following **d**, **i**, **o**, **u**, **x**, or **X** conversion specifier applies to a **long int** or **unsigned long int** argument; an optional **ll** (ell-ell) specifying that a following **d**, **i**, **o**, **u**, **x**, or **X** conversion specifier applies to a **long long int** or **unsigned long long int** argument; an optional **l** specifying that a following **n** conversion specifier applies to a pointer to a **long int** argument; an optional **ll** specifying that a following **n** conversion specifier applies to a pointer to a **long long int** argument; or an optional **L** specifying that a following **e**, **E**, **f**, **g**, or **G** conversion specifier applies to a **long double** argument. If an **h**, **l**, **ll**, or **L** appears with any other conversion specifier, the behavior is undefined.

- A wide character that specifies the type of conversion to be applied.

[5] As noted above, a field width, or precision, or both, may be indicated by an asterisk. In this case, an **int** argument supplies the field width or precision. The arguments specifying field width, or precision, or both, shall appear (in that order) before the argument (if any) to be converted. A negative field width argument is taken as a **-** flag followed by a positive field width. A negative precision argument is taken as if the precision were omitted.

[6] The flag wide characters and their meanings are

- The result of the conversion is left-justified within the field. (It is right-justified if this flag is not specified.)

189. Note that **0** is taken as a flag, not as the beginning of a field width.

+ The result of a signed conversion always begins with a plus or minus sign. (It begins with a sign only when a negative value is converted if this flag is not specified.)

space If the first wide character of a signed conversion is not a sign, or if a signed conversion results in no wide characters, a space is prefixed to the result. If the *space* and **+** flags both appear, the *space* flag is ignored.

The result is to be converted to an ''alternate form.'' For **o** conversion, it increases the precision to force the first digit of the result to be a zero, if necessary. For **x** (or **X**) conversion, a nonzero result has **0x** (or **0X**) prefixed to it. For **a**, **A**, **e**, **E**, **f**, **g**, and **G** conversions, the result always contains a decimal-point wide character, even if no digits follow it. (Normally, a decimal-point wide character appears in the result of these conversions only if a digit follows it.) For **g** and **G** conversions, trailing zeros are *not* be removed from the result. For other conversions, the behavior is undefined.

0 For **d**, **i**, **o**, **u**, **x**, **X**, **a**, **A**, **e**, **E**, **f**, **g**, and **G** conversions, leading zeros (following any indication of sign or base) are used to pad to the field width; no space padding is performed. If the **0** and **-** flags both appear, the **0** flag is ignored. For **d**, **i**, **o**, **u**, **x**, and **X** conversions, if a precision is specified, the **0** flag is ignored. For other conversions, the behavior is undefined.

[7] The conversion specifiers and their meanings are

d,i The **int** argument is converted to signed decimal in the style *[-]dddd*. The precision specifies the minimum number of digits to appear; if the value being converted can be represented in fewer digits, it is expanded with leading zeros. The default precision is 1. The result of converting a zero value with a precision of zero is no wide characters.

o,u,x,X The **unsigned int** argument is converted to unsigned octal (**o**), unsigned decimal (**u**), or unsigned hexadecimal notation (**x** or **X**) in the style *dddd*; the letters **abcdef** are used for **x** conversion and the letters **ABCDEF** for **X** conversion. The precision specifies the minimum number of digits to appear; if the value being converted can be represented in fewer digits, it is expanded with leading zeros. The default precision is 1. The result of converting a zero value with a precision of zero is no wide characters.

f The **double** argument is converted to decimal notation in the style *[-]ddd.ddd*, where the number of digits after the decimal-point wide character is equal to the precision specification. If the precision is missing, it is taken as 6; if the precision is zero and the **#** flag is not specified, no decimal-point wide character appears. If a decimal-point wide character appears, at least one digit appears before it. The value is rounded to the appropriate number of digits.

e,E The **double** argument is converted in the style [-]d.ddde±dd, where there is one digit before the decimal-point wide character (which is nonzero if the argument is nonzero) and the number of digits after it is equal to the precision;

if the precision is missing, it is taken as 6; if the precision is zero and the **#** flag is not specified, no decimal-point wide character appears. The value is rounded to the appropriate number of digits. The **E** conversion specifier produces a number with **E** instead of **e** introducing the exponent. The exponent always contains at least two digits. If the value is zero, the exponent is zero.

g,G The **double** argument is converted in style **f** or **e** (or in style **E** in the case of a **G** conversion specifier), with the precision specifying the number of significant digits. If the precision is zero, it is taken as 1. The style used depends on the value converted; style **e** (or **E**) is used only if the exponent resulting from such a conversion is less than -4 or greater than or equal to the precision. Trailing zeros are removed from the fractional portion of the result; a decimal-point wide character appears only if it is followed by a digit.

a,A The double argument is converted in the style *[−]0xh.hhhhp***p**$\pm$*d*. The number of hexadecimal digits h after the decimal-point wide character is equal to the precision; if the precision is missing and **FLT_RADIX** is a power of 2, then the precision is sufficient for an exact representation of the value; if the precision is missing and **FLT_RADIX** is not a power of 2, then the precision is sufficient to distinguish[190] values of type double, except that trailing zeros may be omitted. The hexadecimal digit to the left of the decimal-point character is nonzero for normalized floating-point numbers and is otherwise unspecified; if the precision is zero and the **#** flag is not specified, no decimal-point wide character appears. The letters **abcdef** are used for a conversion and the letters **ABCDEF** for **A** conversion. The a conversion specifier will produce a number with **x** and **p** and the **A** conversion specifier will produce a number with **X** and **P**. The exponent always contains at least one digit, and only as many more digits as necessary to represent the decimal exponent of 2. If the value is zero, the exponent is zero.

c If no **l** qualifier is present, the **int** argument is converted to a wide character as if by calling **btowc** and the resulting wide character is written. Otherwise, the **wint_t** argument is converted to **wchar_t** and written.

s If no **l** qualifier is present, the argument shall be a pointer to a character array containing a multibyte sequence beginning in the initial shift state. Characters from the array are converted as if by repeated calls to the **mbrtowc** function, with the conversion state described by an **mbstate_t** object initialized to zero

190. The precision p is sufficient to distinguish values of the source type if [*FF* missing text here] where *b* is **FLT_RADIX** and *n* is the number of base-b digits in the significand of the source type. A smaller *p* might suffice depending on the implementation's scheme for determining the digit to the left of the decimal-point wide character.

[*FF* Where does this paragraph go?] Binary implementations can choose the hexadecimal digit to the left of the decimal-point wide character so that subsequent digits align to nibble (4-bit) boundaries.

before the first multibyte character is converted, and written up to (but not including) the terminating null wide character. If the precision is specified, no more than that many wide characters are written. If the precision is not specified or is greater than the size of the converted array, the converted array shall contain a null wide character.

If an **l** qualifier is present, the argument shall be a pointer to an array of **wchar_t** type. Wide characters from the array are written up to (but not including) a terminating null wide character. If the precision is specified, no more than that many wide characters are written. If the precision is not specified or is greater than the size of the array, the array shall contain a null wide character.

p The argument shall be a pointer to **void**. The value of the pointer is converted to a sequence of printable wide characters, in an implementation-defined manner.

n The argument shall be a pointer to an integer into which is *written* the number of wide characters written to the output stream so far by this call to **fwprintf**. No argument is converted.

% A **%** wide character is written. No argument is converted. The complete conversion specification shall be **%%**.

[8] If a conversion specification is invalid, the behavior is undefined.[191]

[9] If any argument is, or points to, a union or an aggregate (except for an array of **char** type using **%s** conversion, an array of **wchar_t** type using **%ls** conversion, or a pointer using **%p** conversion), the behavior is undefined.

[10] In no case does a nonexistent or small field width cause truncation of a field; if the result of a conversion is wider than the field width, the field is expanded to contain the conversion result.

[11] For **a** and **A** conversions, if **FLT_RADIX** is a power of 2, the value is correctly rounded to a hexadecimal floating number with the given precision.

Recommended practice

[12] If **FLT_RADIX** is not a power of 2, the result is one of the two adjacent numbers in hexadecimal floating style with the given precision, with the extra stipulation that the error have a correct sign for the current rounding direction.

Returns

[13] The **fwprintf** function returns the number of wide characters transmitted, or a negative value if an output error occurred.

---

191. See ‘‘future library directions’’ (7.18).

Environmental limit

[14] The minimum value for the maximum number of wide characters produced by any single conversion shall be 509.

Example

[15] To print a date and time in the form ‘‘Sunday, July 3, 10:02’’ followed by **pi** to five decimal places:

```
#include <math.h>
#include <stdio.h>
#include <wchar.h>
/*...*/
wchar_t *weekday, *month;  /* pointers to wide strings */
int day, hour, min;
fwprintf(stdout, L"%ls, %ls %d, %.2d:%.2d\n",
     weekday, month, day, hour, min);
fwprintf(stdout, L"pi = %.5f\n", 4 * atan(1.0));
```

[16] Forward References: the **btowc** function (7.17.6.1.1), the **mbrtowc** function (7.17.6.3.2).

7.17.2.2 The fwscanf function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
int fwscanf(FILE * restrict stream,
     const wchar_t * restrict format, ...);
```

Description

[2] The **fwscanf** function reads input from the stream pointed to by **stream**, under control of the wide string pointed to by **format** that specifies the admissible input sequences and how they are to be converted for assignment, using subsequent arguments as pointers to the objects to receive the converted input. If there are insufficient arguments for the format, the behavior is undefined. If the format is exhausted while arguments remain, the excess arguments are evaluated (as always) but are otherwise ignored.

[3] The format is composed of zero or more directives: one or more white-space wide characters; an ordinary wide character (neither **%** nor a white-space wide character); or a conversion specification. Each conversion specification is introduced by a **%**. After the **%**, the following appear in sequence:

- An optional assignment-suppressing wide character *****.

- An optional nonzero decimal integer that specifies the maximum field width (in wide characters).
- An optional **h**, **l** (ell), **ll** (ell-ell), or **L** indicating the size of the receiving object. The conversion specifiers **c**, **s**, and **[** shall be preceded by **l** if the corresponding argument is a pointer to **wchar_t** rather than a pointer to a character type. The conversion specifiers **d**, **i**, and **n** shall be preceded by **h** if the corresponding argument is a pointer to **short int** rather than a pointer to **int**, by **l** if it is a pointer to **long int**, or by **ll** if it is a pointer to **long long int**. Similarly, the conversion specifiers **o**, **u**, and **x** shall be preceded by **h** if the corresponding argument is a pointer to **unsigned short int** rather than a pointer to **unsigned int**, by **l** if it is a pointer to **unsigned long int**, or by **ll** if it is a pointer to **unsigned long long int**. Finally, the conversion specifiers **e**, **f**, and **g** shall be preceded by **l** if the corresponding argument is a pointer to **double** rather than a pointer to **float**, or by **L** if it is a pointer to **long double**. If an **h**, **l**, **ll**, or **L** appears with any other conversion specifier, the behavior is undefined.
- A wide character that specifies the type of conversion to be applied. The valid conversion specifiers are described below.

[4] The **fwscanf** function executes each directive of the format in turn. If a directive fails, as detailed below, the **fwscanf** function returns. Failures are described as input failures (if an encoding error occurs or due to the unavailability of input characters), or matching failures (due to inappropriate input).

[5] A directive composed of white-space wide character(s) is executed by reading input up to the first non-white-space wide character (which remains unread), or until no more wide characters can be read.

[6] A directive that is an ordinary wide character is executed by reading the next wide character of the stream. If the wide character differs from the directive, the directive fails, and the differing and subsequent wide characters remain unread.

[7] A directive that is a conversion specification defines a set of matching input sequences, as described below for each specifier. A conversion specification is executed in the following steps:

[8] Input white-space wide characters (as specified by the **iswspace** function) are skipped, unless the specification includes a **c** or **n** specifier.[192]

[9] An input item is read from the stream, unless the specification includes an **n** specifier. An input item is defined as the longest sequence of input wide characters, not exceeding any specified field width, which is, or is a prefix of, a matching

192. These white-space wide characters are not counted against a specified field width.

sequence. The first wide character, if any, after the input item remains unread. If the length of the input item is zero, the execution of the directive fails: this condition is a matching failure, unless end-of-file, an encoding error, or a read error prevented input from the stream, in which case it is an input failure.

[10] Except in the case of a **`%`** specifier, the input item (or, in the case of a **`%n`** directive, the count of input wide characters) is converted to a type appropriate to the conversion specifier. If the input item is not a matching sequence, the execution of the directive fails: this condition is a matching failure. Unless assignment suppression was indicated by a **`*`**, the result of the conversion is placed in the object pointed to by the first argument following the **`format`** argument that has not already received a conversion result. If this object does not have an appropriate type, or if the result of the conversion cannot be represented in the space provided, the behavior is undefined.

[11] The following conversion specifiers are valid:

`d` Matches an optionally signed decimal integer, whose format is the same as expected for the subject sequence of the **`wcstol`** function with the value 10 for the **`base`** argument. The corresponding argument shall be a pointer to integer.

`i` Matches an optionally signed integer, whose format is the same as expected for the subject sequence of the **`wcstol`** function with the value 0 for the **`base`** argument. The corresponding argument shall be a pointer to integer.

`o` Matches an optionally signed octal integer, whose format is the same as expected for the subject sequence of the **`wcstoul`** function with the value 8 for the **`base`** argument. The corresponding argument shall be a pointer to unsigned integer.

`u` Matches an optionally signed decimal integer, whose format is the same as expected for the subject sequence of the **`wcstoul`** function with the value 10 for the **`base`** argument. The corresponding argument shall be a pointer to unsigned integer.

`x` Matches an optionally signed hexadecimal integer, whose format is the same as expected for the subject sequence of the **`wcstoul`** function with the value 16 for the **`base`** argument. The corresponding argument shall be a pointer to unsigned integer.

`e,f,g` Matches an optionally signed floating-point number, whose format is the same as expected for the subject sequence of the **`wcstod`** function. The corresponding argument shall be a pointer to floating.

`s` Matches a sequence of non-white-space wide characters. If no **`l`** qualifier is present, characters from the input field are converted as if by repeated calls to the **`wcrtomb`** function, with the conversion state described by an **`mbstate_t`** object initialized to zero before the first wide character is converted. The corresponding argument shall be a pointer to a character array large enough to accept the sequence and a terminating null character, which will be added automatically.

Otherwise, the corresponding argument shall be a pointer to the initial element of an array of **wchar_t** type large enough to accept the sequence and a terminating null wide character, which will be added automatically.

[Matches a nonempty sequence of wide characters from a set of expected characters (the *scanset*). If no **l** qualifier is present, characters from the input field are converted as if by repeated calls to the **wcrtomb** function, with the conversion state described by an **mbstate_t** object initialized to zero before the first wide character is converted. The corresponding argument shall be a pointer to a character array large enough to accept the sequence and a terminating null character, which will be added automatically.

[12] If an **l** qualifier is present, the corresponding argument shall be a pointer to the initial element of an array of **wchar_t** type large enough to accept the sequence and a terminating null wide character, which will be added automatically.

[13] The conversion specifier includes all subsequent wide characters in the **format** string, up to and including the matching right bracket wide character (**]**). The wide characters between the brackets (the *scanlist*) comprise the scanset, unless the wide character after the left bracket is a circumflex (**^**), in which case the scanset contains all wide characters that do not appear in the scanlist between the circumflex and the right bracket. If the conversion specifier begins with **[]** or **[^]**, the right bracket wide character is in the scanlist and the next right bracket wide character is the matching right bracket that ends the specification; otherwise the first right bracket wide character is the one that ends the specification. If a **-** wide character is in the scanlist and is not the first, nor the second where the first wide character is a **^**, nor the last character, the behavior is implementation-defined.

c Matches a sequence of wide characters of the number specified by the field width (1 if no field width is present in the directive). If no **l** qualifier is present, characters from the input field are converted as if by repeated calls to the **wcrtomb** function, with the conversion state described by an **mbstate_t** object initialized to zero before the first wide character is converted. The corresponding argument shall be a pointer to a character array large enough to accept the sequence. No null character is added.

[14] If an **l** qualifier is present, the corresponding argument shall be a pointer to the initial element of an array of **wchar_t** type large enough to accept the sequence. No null wide character is added.

p Matches an implementation-defined set of sequences, which should be the same as the set of sequences that may be produced by the **%p** conversion of the **fwprintf** function. The corresponding argument shall be a pointer to a pointer to **void**. The interpretation of the input item is implementation-defined. If the input item is a value converted earlier during the same program execution, the pointer that results shall compare equal to that value; otherwise the behavior of the **%p** conversion is undefined.

n No input is consumed. The corresponding argument shall be a pointer to integer into which is to be written the number of wide characters read from the input stream so far by this call to the **fwscanf** function. Execution of a **%n** directive does not increment the assignment count returned at the completion of execution of the **fwscanf** function. No argument is converted, but one is consumed. If the conversion specification with this conversion specifier is not one of **%n**, **%ln**, **%lln**, or **%hn**, the behavior is undefined.

% Matches a single **%**; no conversion or assignment occurs. The complete conversion specification shall be **%%**

[15] If a conversion specification is invalid, the behavior is undefined.[193]

[16] The conversion specifiers **E**, **G**, and **X** are also valid and behave the same as, respectively, **e**, **g**, and **x**.

[17] If end-of-file is encountered during input, conversion is terminated. If end-of-file occurs before any wide characters matching the current directive have been read (other than leading white space, where permitted), execution of the current directive terminates with an input failure; otherwise, unless execution of the current directive is terminated with a matching failure, execution of the following directive (other than **%n**, if any) is terminated with an input failure.

[18] Trailing white space (including new-line wide characters) is left unread unless matched by a directive. The success of literal matches and suppressed assignments is not directly determinable other than via the **%n** directive.

Returns

[19] The **fwscanf** function returns the value of the macro **EOF** if an input failure occurs before any conversion. Otherwise, the **fwscanf** function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early matching failure.

Examples

1. The call:

```
#include <stdio.h>
#include <wchar.h>
/*...*/
int n, i; float x; wchar_t name[50];
n = fwscanf(stdin, L"%d%f%ls", &i, &x, name);
```

193. See ‘‘future library directions’’ (7.18).

[20] with the input line:

```
25 54.32E-1 thompson
```

[21] will assign to **n** the value **3**, to **i** the value **25**, to **x** the value **5.432**, and to **name** the sequence **thompson\0**.

2. The call:

```
#include <stdio.h>
#include <wchar.h>
/*...*/
int i; float x; double y;
fwscanf(stdin, L"%2d%f%*d %lf", &i, &x, &y);
```

[22] with input:

```
56789 0123 56a72
```

[23] will assign to **i** the value **56** and to **x** the value **7.10.0**, will skip past **0123**, and will assign to **y** the value **56.0**. The next wide character read from the input stream will be **a**.

[24] Forward References: the **wcstod** function (7.17.4.1.1), the **wcstol** function (7.17.4.1.2), the **wcstoul** function (7.17.4.1.3), the **wcrtomb** function (7.17.6.3.3).

7.17.2.3 The wprintf function

Synopsis

[1]

```
#include <wchar.h>
int wprintf(const wchar_t * restrict format, ...);
```

Description

[2] The **wprintf** function is equivalent to **fwprintf** with the argument **stdout** interposed before the arguments to **wprintf**.

Returns

[3] The **wprintf** function returns the number of wide characters transmitted, or a negative value if an output error occurred.

7.17.2.4 The wscanf function

Synopsis

[1]

```
#include <wchar.h>
int wscanf(const wchar_t * restrict format, ...);
```

Description

[2] The **wscanf** function is equivalent to **fwscanf** with the argument **stdin** interposed before the arguments to **wscanf**.

Returns

[3] The **wscanf** function returns the value of the macro **EOF** if an input failure occurs before any conversion. Otherwise, the **wscanf** function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early matching failure.

7.17.2.5 The swprintf function

Synopsis

[1]

```
#include <wchar.h>
int swprintf(wchar_t * restrict s,
     size_t n,
     const wchar_t * restrict format, ...);
```

Description

[2] The **swprintf** function is equivalent to **fwprintf**, except that the argument **s** specifies an array of wide characters into which the generated output is to be written, rather than written to a stream. No more than **n** wide characters are written, including a terminating null wide character, which is always added (unless **n** is zero).

Returns

[3] The **swprintf** function returns the number of wide characters written in the array, not counting the terminating null wide character, or a negative value if **n** or more wide characters were requested to be written.

7.17.2.6 The swscanf function

Synopsis

[1]

```
#include <wchar.h>
int swscanf(const wchar_t * restrict s,
     const wchar_t * restrict format, ...);
```

Description

[2] The **swscanf** function is equivalent to **fwscanf**, except that the argument **s** specifies a wide string from which the input is to be obtained, rather than from a stream. Reaching the end of the wide string is equivalent to encountering end-of-file for the **fwscanf** function.

Returns

[3] The **swscanf** function returns the value of the macro **EOF** if an input failure occurs before any conversion. Otherwise, the **swscanf** function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early matching failure.

7.17.2.7 The vfwprintf function

Synopsis

[1]

```
#include <stdarg.h>
#include <stdio.h>
#include <wchar.h>
int vfwprintf(FILE * restrict stream,
     const wchar_t * restrict format,
     va_list arg);
```

Description

[2] The **vfwprintf** function is equivalent to **fwprintf**, with the variable argument list replaced by **arg**, which shall have been initialized by the **va_start** macro (and possibly subsequent **va_arg** calls). The **vfwprintf** function does not invoke the **va_end** macro.[194]

Returns

[3] The **vfwprintf** function returns the number of wide characters transmitted, or a negative value if an output error occurred.

Example

[4] The following shows the use of the **vfwprintf** function in a general error-reporting routine.

194. As the functions **vfwprintf**, **vswprintf**, and **vwprintf** invoke the **va_arg** macro, the value of **arg** after the return is unspecified.

```
#include <stdarg.h>
#include <stdio.h>
#include <wchar.h>

void error(char *function_name, wchar_t *format, ...)
{
     va_list args;

     va_start(args, format);
     /* print out name of function causing error */
     fwprintf(stderr, L"ERROR in %s: ", function_name);
     /* print out remainder of message */
     vfwprintf(stderr, format, args);
     va_end(args);
}
```

7.17.2.8 The `vwprintf` function

Synopsis

[1]

```
#include <stdarg.h>
#include <wchar.h>
int vwprintf(const wchar_t * restrict format,
     va_list arg);
```

Description

[2] The **`vwprintf`** function is equivalent to **`wprintf`**, with the variable argument list replaced by **`arg`**, which shall have been initialized by the **`va_start`** macro (and possibly subsequent **`va_arg`** calls). The **`vwprintf`** function does not invoke the **`va_end`** macro.

Returns

[3] The **`vwprintf`** function returns the number of wide characters transmitted, or a negative value if an output error occurred.

7.17.2.9 The `vswprintf` function

Synopsis

[1]

```
#include <stdarg.h>
#include <wchar.h>
int vswprintf(wchar_t * restrict s,
     size_t n,
     const wchar_t * restrict format,
     va_list arg);
```

Description

[2] The **vswprintf** function is equivalent to **swprintf**, with the variable argument list replaced by **arg**, which shall have been initialized by the **va_start** macro (and possibly subsequent **va_arg** calls). The **vswprintf** function does not invoke the **va_end** macro.

Returns

[3] The **vswprintf** function returns the number of wide characters written in the array, not counting the terminating null wide character, or a negative value if **n** or more wide characters were requested to be generated.

7.17.3 Wide-character input/output functions

7.17.3.1 The fgetwc function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
wint_t fgetwc(FILE *stream);
```

Description

[2] The **fgetwc** function obtains the next wide character (if present) from the input stream pointed to by **stream**, and advances the associated file position indicator for the stream (if defined).

Returns

[3] The **fgetwc** function returns the next wide character from the input stream pointed to by **stream**. If the stream is at end-of-file, the end-of-file indicator for the stream is set and **fgetwc** returns **WEOF**. If a read error occurs, the error indicator for the stream is set and **fgetwc** returns **WEOF**. If an encoding error occurs (including too few bytes), the value of the macro **EILSEQ** is stored in **errno** and **fgetwc** returns **WEOF**.[195]

195. An end-of-file and a read error can be distinguished by use of the **feof** and **ferror** functions. Also, **errno** will be set to **EILSEQ** by input/output functions only if an encoding error occurs.

7.17.3.2 The `fgetws` function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
wchar_t *fgetws(wchar_t * restrict s,
     int n, FILE * restrict stream);
```

description

[2] The **`fgetws`** function reads at most one less than the number of wide characters specified by **`n`** from the stream pointed to by **`stream`** into the array pointed to by **`s`**. No additional wide characters are read after a new-line wide character (which is retained) or after end-of-file. A null wide character is written immediately after the last wide character read into the array.

Returns

[3] The **`fgetws`** function returns **`s`** if successful. If end-of-file is encountered and no characters have been read into the array, the contents of the array remain unchanged and a null pointer is returned. If a read or encoding error occurs during the operation, the array contents are indeterminate and a null pointer is returned.

7.17.3.3 The `fputwc` function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
wint_t fputwc(wchar_t c, FILE *stream);
```

Description

[2] The **`fputwc`** function writes the wide character specified by **`c`** to the output stream pointed to by **`stream`**, at the position indicated by the associated file position indicator for the stream (if defined), and advances the indicator appropriately. If the file cannot support positioning requests, or if the stream was opened with append mode, the character is appended to the output stream.

Returns

[3] The **`fputwc`** function returns the wide character written. If a write error occurs, the error indicator for the stream is set and **`fputwc`** returns **`WEOF`**. If an encoding error occurs, the value of the macro **`EILSEQ`** is stored in **`errno`** and **`fputwc`** returns **`WEOF`**.

7.17.3.4 The `fputws` function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
int fputws(const wchar_t * restrict s,
     FILE * restrict stream);
```

Description

[2] The **`fputws`** function writes the wide string pointed to by **`s`** to the stream pointed to by **`stream`**. The terminating null wide character is not written.

Returns

[3] The **`fputws`** function returns **`EOF`** if a write or encoding error occurs; otherwise, it returns a nonnegative value.

7.17.3.5 The `getwc` function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
wint_t getwc(FILE *stream);
```

Description

[2] The **`getwc`** function is equivalent to **`fgetwc`**, except that if it is implemented as a macro, it may evaluate **`stream`** more than once, so the argument should never be an expression with side effects.

Returns

[3] The **`getwc`** function returns the next wide character from the input stream pointed to by **`stream`** or **`WEOF`**.

7.17.3.6 The `getwchar` function

Synopsis

[1]

```
#include <wchar.h>
wint_t getwchar(void);
```

Description

[2] The **`getwchar`** function is equivalent to **`getwc`** with the argument **`stdin`**.

Returns

[3] The **`getwchar`** function returns the next wide character from the input stream pointed to by **`stdin`** or **`WEOF`**.

7.17.3.7 The `putwc` function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
wint_t putwc(wchar_t c, FILE *stream);
```

Description

[2] The **`putwc`** function is equivalent to **`fputwc`**, except that if it is implemented as a macro, it may evaluate **`stream`** more than once, so the argument should never be an expression with side effects.

Returns

[3] The **`putwc`** function returns the wide character written or **`WEOF`**.

7.17.3.8 The `putwchar` function

Synopsis

[1]

```
#include <wchar.h>
wint_t putwchar(wchar_t c);
```

Description

[2] The **`putwchar`** function is equivalent to **`putwc`** with the second argument **`stdout`**.

Returns

[3] The **`putwchar`** function returns the character written or **`WEOF`**.

7.17.3.9 The `ungetwc` function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
wint_t ungetwc(wint_t c, FILE *stream);
```

Description

[2] The **`ungetwc`** function pushes the wide character specified by **`c`** back onto the input stream pointed to by **`stream`**. The pushed-back wide characters will be returned by subsequent reads on that stream in the reverse order of their pushing. A successful intervening call (with the stream pointed to by **stream**) to a file positioning function (**fseek**, **fsetpos**, or **rewind**) discards any pushed-back wide characters for the stream. The external storage corresponding to the stream is unchanged.

[3] One wide character of pushback is guaranteed, even if the call to the **ungetwc** function follows just after a call to a formatted wide character input function (**fwscanf** or **wscanf**). If the **ungetwc** function is called too many times on the same stream without an intervening read or file positioning operation on that stream, the operation may fail.

[4] If the value of **c** equals that of the macro **WEOF**, the operation fails and the input stream is unchanged.

[5] A successful call to the **ungetwc** function clears the end-of-file indicator for the stream. The value of the file position indicator for the stream after reading or discarding all pushed-back wide characters is the same as it was before the wide characters were pushed back. For a text or binary stream, the value of its file position indicator after a successful call to the **ungetwc** function is unspecified until all pushed-back wide characters are read or discarded.

Returns

[6] The **ungetwc** function returns the wide character pushed back, or **WEOF** if the operation fails.

7.17.3.10 The fwide function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
int fwide(FILE *stream, int mode);
```

Description

[2] The **fwide** function determines the orientation of the stream pointed to by **stream**. If **mode** is greater than zero, the function first attempts to make the stream wide oriented. If **mode** is less than zero, the function first attempts to make the stream byte oriented.[196] Otherwise, **mode** is zero and the function does not alter the orientation of the stream.

Returns

[3] The **fwide** function returns a value greater than zero if, after the call, the stream

196. If the orientation of the stream has already been determined, **fwide** does not change it.

has wide orientation, a value less than zero if the stream has byte orientation, or zero if the stream has no orientation.

7.17.4 General wide-string utilities

[1] The header **`<wchar.h>`** declares a number of functions useful for wide-string manipulation. Various methods are used for determining the lengths of the arrays, but in all cases a **`wchar_t *`** argument points to the initial (lowest addressed) element of the array. If an array is accessed beyond the end of an object, the behavior is undefined.

7.17.4.1 Wide-string numeric conversion functions

7.17.4.1.1 The `wcstod` function

Synopsis

[1]

```
#include <wchar.h>
double wcstod(const wchar_t *nptr, wchar_t **endptr);
```

Description

[2] The **`wcstod`** function converts the initial portion of the wide string pointed to by **`nptr`** to **`double`** representation. First, it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space wide characters (as specified by the **`iswspace`** function), a subject sequence resembling a floating-point constant; and a final wide string of one or more unrecognized wide characters, including the terminating null wide character of the input wide string. Then, it attempts to convert the subject sequence to a floating-point number, and returns the result.

[3] The expected form of the subject sequence is an optional plus or minus sign, then one of the following:

— a nonempty sequence of decimal digits optionally containing a decimal-point wide character, then an optional exponent part as defined for the corresponding single-byte characters in subclause 6.1.3.1;

— a 0x or 0X, then a nonempty sequence of hexadecimal digits optionally containing a decimal-point wide character, then an optional binary-exponent part, where either the decimal-point character or the binary-exponent part is present;

but no floating suffix. The subject sequence is defined as the longest initial subsequence of the input wide string, starting with the first non-white-space wide character, that is of the expected form. The subject sequence contains no wide characters if the input wide string is empty or consists entirely of white space, or if the first non-white-space wide character is other than a sign, a digit, or a decimal-point wide character.

[4] If the subject sequence has the expected form, the sequence of wide characters starting with the first digit or the decimal-point wide character (whichever occurs first) is interpreted as a floating constant according to the rules of subclause 6.1.3.1, except that the decimal-point wide character is used in place of a period, and that if neither an exponent part, a binary-exponent part, nor a decimal-point wide character appears, a decimal point is assumed to follow the last digit in the wide string. If the subject sequence begins with a minus sign, the value resulting from the conversion is negated. A pointer to the final wide string is stored in the object pointed to by **`endptr`**, provided that **`endptr`** is not a null pointer.

[5] Additional implementation-defined subject sequences may be accepted.

[6] If the subject sequence has the hexadecimal form and **`FLT_RADIX`** is a power of 2, then the value resulting from the conversion is correctly rounded.

[7] If the subject sequence is empty or does not have the expected form, no conversion is performed; the value of **`nptr`** is stored in the object pointed to by **`endptr`**, provided that **`endptr`** is not a null pointer.

Recommended practice

[8] If the subject sequence has the hexadecimal form and **`FLT_RADIX`** is not a power of 2, then the result is one of the two numbers in the appropriate internal format that are adjacent to the hexadecimal floating source value, with the extra stipulation that the error have a correct sign for the current rounding direction.

Returns

[9] The **`wcstod`** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, plus or minus **`HUGE_VAL`** is returned (according to the sign of the value), and the value of the macro **`ERANGE`** is stored in **`errno`**. If the correct value would cause underflow, zero is returned and the value of the macro **`ERANGE`** is stored in **`errno`**.

7.17.4.1.2 The `wcstol` function

Synopsis

[1]

```
#include <wchar.h>
long int wcstol(
     const wchar_t * restrict nptr,
     wchar_t ** restrict endptr,
     int base);
```

Description

[2] The **`wcstol`** function converts the initial portion of the wide string pointed to by **`nptr`** to **`long int`** representation. First, it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space wide characters (as specified by the **`iswspace`** function), a subject sequence resembling an integer represented in some radix determined by the value of **`base`**, and a final wide string of one or more unrecognized wide characters, including the terminating null wide character of the input wide string. Then, it attempts to convert the subject sequence to an integer, and returns the result.

[3] If the value of **base** is zero, the expected form of the subject sequence is that of an integer constant as described for the corresponding single-byte characters in subclause 6.1.3.2, optionally preceded by a plus or minus sign, but not including an integer suffix. If the value of **base** is between 2 and 36 (inclusive), the expected form of the subject sequence is a sequence of letters and digits representing an integer with the radix specified by **base**, optionally preceded by a plus or minus sign, but not including an integer suffix. The letters from **a** (or **A**) through **z** (or **Z**) are ascribed the values 10 through 35; only letters and digits whose ascribed values are less than that of **base** are permitted. If the value of **base** is 16, the wide characters **0x** or **0X** may optionally precede the sequence of letters and digits, following the sign if present.

[4] The subject sequence is defined as the longest initial subsequence of the input wide string, starting with the first non-white-space wide character, that is of the expected form. The subject sequence contains no wide characters if the input wide string is empty or consists entirely of white space, or if the first non-white-space wide character is other than a sign or a permissible letter or digit.

[5] If the subject sequence has the expected form and the value of **base** is zero, the sequence of wide characters starting with the first digit is interpreted as an integer constant according to the rules of subclause 6.1.3.2. If the subject sequence has the expected form and the value of **base** is between 2 and 36, it is used as the base for conversion, ascribing to each letter its value as given above. If the subject sequence begins with a minus sign, the value resulting from the conversion is negated. A pointer to the final wide string is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

[6] Additional implementation-defined subject sequences may be accepted.

[7] If the subject sequence is empty or does not have the expected form, no conversion is performed; the value of **nptr** is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

Returns

[8] The **wcstol** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, **LONG_MAX** or **LONG_MIN** is returned (according to the sign of the value), and the value of the macro **ERANGE** is stored in **errno**.

7.17.4.1.3 The `wcstoll` function

Synopsis

[1]

```
#include <wchar.h>
long long int wcstoll(
     const wchar_t * restrict nptr,
     wchar_t ** restrict endptr,
     int base);
```

Description

[2] The **wcstoll** function is equivalent to the **wcstol** function, except that it converts the initial portion of the wide string pointed to by **nptr** to **long long int** representation.

Returns

[3] The **wcstoll** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, **LLONG_MAX** or **LLONG_MIN** is returned (according to the sign of the value), and the value of the macro **ERANGE** is stored in **errno**.

7.17.4.1.4 The wcstoul function

Synopsis

[1]

```
#include <wchar.h>
unsigned long int wcstoul(
     const wchar_t * restrict nptr,
     wchar_t ** restrict endptr,
     int base);
```

Description

[2] The **wcstoul** function converts the initial portion of the wide string pointed to by **nptr** to **unsigned long int** representation. First, it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space wide characters (as specified by the **iswspace** function), a subject sequence resembling an unsigned integer represented in some radix determined by the value of **base**, and a final wide string of one or more unrecognized wide characters, including the terminating null wide character of the input wide string. Then, it attempts to convert the subject sequence to an unsigned integer, and returns the result.

[3] If the value of **base** is zero, the expected form of the subject sequence is that of an integer constant as described for the corresponding single-byte characters in subclause 6.1.3.2, optionally preceded by a plus or minus sign, but not including an integer suffix. If the value of **base** is between 2 and 36 (inclusive), the expected form of the subject sequence is a sequence of letters and digits representing an integer with the radix specified by **base**, optionally preceded by a plus or minus sign, but not including an integer suffix. The letters from **a** (or **A**) through **z** (or **Z**) are ascribed the values 10 through 35; only letters and digits whose ascribed values are less than that of **base** are permitted. If the value of **base** is 16, the wide characters

0x or **0X** may optionally precede the sequence of letters and digits, following the sign if present.

[4] The subject sequence is defined as the longest initial subsequence of the input wide string, starting with the first non-white-space wide character, that is of the expected form. The subject sequence contains no wide characters if the input wide string is empty or consists entirely of white space, or if the first non-white-space wide character is other than a sign or a permissible letter or digit.

[5] If the subject sequence has the expected form and the value of **base** is zero, the sequence of wide characters starting with the first digit is interpreted as an integer constant according to the rules of subclause 6.1.3.2. If the subject sequence has the expected form and the value of **base** is between 2 and 36, it is used as the base for conversion, ascribing to each letter its value as given above. If the subject sequence begins with a minus sign, the value resulting from the conversion is negated. A pointer to the final wide string is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

[6] Additional implementation-defined subject sequences may be accepted.

[7] If the subject sequence is empty or does not have the expected form, no conversion is performed; the value of **nptr** is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

Returns

[8] The **wcstoul** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, **ULONG_MAX** is returned, and the value of the macro **ERANGE** is stored in **errno**.

7.17.4.1.5 The wcstoull function

Synopsis

[1]

```
#include <wchar.h>
unsigned long long int wcstoull(
     const wchar_t * restrict nptr,
     wchar_t ** restrict endptr,
     int base);
```

Description

[2] The **wcstoull** function is equivalent to the **wcstoul** function, except that it converts the initial portion of the wide string pointed to to **unsigned long long int** representation.

Returns

[3] The **wcstoull** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, **ULLONG_MAX** is returned, and the value of the macro **ERANGE** is stored in **errno**.

7.17.4.2 Wide-string copying functions

7.17.4.2.1 The wcscpy function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wcscpy(wchar_t * restrict s1,
     const wchar_t * restrict s2);
```

Description

[2] The **wcscpy** function copies the wide string pointed to by **s2** (including the terminating null wide character) into the array pointed to by **s1**.

Returns

[3] The **wcscpy** function returns the value of **s1**.

7.17.4.2.2 The wcsncpy function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wcsncpy(wchar_t * restrict s1,
     const wchar_t * restrict s2,
     size_t n);
```

Description

[2] The **wcsncpy** function copies not more than **n** wide characters (those that follow a null wide character are not copied) from the array pointed to by **s2** to the array pointed to by **s1**.[197]

[3] If the array pointed to by **s2** is a wide string that is shorter than **n** wide characters, null wide characters are appended to the copy in the array pointed to by **s1**, until **n** wide characters in all have been written.

Returns

197. Thus, if there is no null wide character in the first **n** wide characters of the array pointed to by **s2**, the result will not be null-terminated.

[4] The **wcsncpy** function returns the value of **s1**.

7.17.4.3 Wide-string concatenation functions

7.17.4.3.1 The wcscat function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wcscat(wchar_t * restrict s1,
     const wchar_t * restrict s2);
```

Description

[2] The **wcscat** function appends a copy of the wide string pointed to by **s2** (including the terminating null wide character) to the end of the wide string pointed to by **s1**. The initial wide character of **s2** overwrites the null wide character at the end of **s1**.

Returns

[3] The **wcscat** function returns the value of **s1**.

7.17.4.3.2 The wcsncat function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wcsncat(wchar_t * restrict s1,
     const wchar_t * restrict s2,
     size_t n);
```

Description

[2] The **wcsncat** function appends not more than **n** wide characters (a null wide character and those that follow it are not appended) from the array pointed to by **s2** to the end of the wide string pointed to by **s1**. The initial wide character of **s2** overwrites the null wide character at the end of **s1**. A terminating null wide character is always appended to the result.[198]

Returns

[3] The **wcsncat** function returns the value of **s1**.

---

198. Thus, the maximum number of wide characters that can end up in the array pointed to by **s1** is **wcslen(s1)+n+1**.

7.17.4.4 Wide-string comparison functions

[1] Unless explicitly stated otherwise, the functions described in this subclause order two wide characters the same way as two integers of the underlying integral type designated by **`wchar_t`**.

7.17.4.4.1 The `wcscmp` function

Synopsis

[1]

```
#include <wchar.h>
int wcscmp(const wchar_t *s1, const wchar_t *s2);
```

Description

[2] The **`wcscmp`** function compares the wide string pointed to by **`s1`** to the wide string pointed to by **`s2`**.

Returns

[3] The **`wcscmp`** function returns an integer greater than, equal to, or less than zero, accordingly as the wide string pointed to by **`s1`** is greater than, equal to, or less than the wide string pointed to by **`s2`**.

7.17.4.4.2 The `wcscoll` function

Synopsis

[1]

```
#include <wchar.h>
int wcscoll(const wchar_t *s1, const wchar_t *s2);
```

Description

[2] The **`wcscoll`** function compares the wide string pointed to by **`s1`** to the wide string pointed to by **`s2`**, both interpreted as appropriate to the **`LC_COLLATE`** category of the current locale.

Returns

[3] The **`wcscoll`** function returns an integer greater than, equal to, or less than zero, accordingly as the wide string pointed to by **`s1`** is greater than, equal to, or less than the wide string pointed to by **`s2`** when both are interpreted as appropriate to the current locale.

7.17.4.4.3 The `wcsncmp` function

Synopsis

[1]

```
#include <wchar.h>
int wcsncmp(const wchar_t *s1, const wchar_t *s2,
     size_t n);
```

Description

[2] The **wcsncmp** function compares not more than **n** wide characters (those that follow a null wide character are not compared) from the array pointed to by **s1** to the array pointed to by **s2**.

Returns

[3] The **wcsncmp** function returns an integer greater than, equal to, or less than zero, accordingly as the possibly null-terminated array pointed to by **s1** is greater than, equal to, or less than the possibly null-terminated array pointed to by **s2**.

7.17.4.4.4 The wcsxfrm function

Synopsis

[1]

```
#include <wchar.h>
size_t wcsxfrm(wchar_t * restrict s1,
     const wchar_t * restrict s2,
     size_t n);
```

Description

[2] The **wcsxfrm** function transforms the wide string pointed to by **s2** and places the resulting wide string into the array pointed to by **s1**. The transformation is such that if the **wcscmp** function is applied to two transformed wide strings, it returns a value greater than, equal to, or less than zero, corresponding to the result of the **wcscoll** function applied to the same two original wide strings. No more than **n** wide characters are placed into the resulting array pointed to by **s1**, including the terminating null wide character. If **n** is zero, **s1** is permitted to be a null pointer.

Returns

[3] The **wcsxfrm** function returns the length of the transformed wide string (not including the terminating null wide character). If the value returned is **n** or greater, the contents of the array pointed to by **s1** are indeterminate.

Example

[4] The value of the following expression is the length of the array needed to hold the transformation of the wide string pointed to by **s**:

```
1 + wcsxfrm(NULL, s, 0)
```

7.17.4.5 Wide-string search functions

7.17.4.5.1 The `wcschr` function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wcschr(const wchar_t *s, wchar_t c);
```

Description

[2] The `wcschr` function locates the first occurrence of `c` in the wide string pointed to by `s`. The terminating null wide character is considered to be part of the wide string.

Returns

[3] The `wcschr` function returns a pointer to the located wide character, or a null pointer if the wide character does not occur in the wide string.

7.17.4.5.2 The `wcscspn` function

Synopsis

[1]

```
#include <wchar.h>
size_t wcscspn(const wchar_t *s1, const wchar_t *s2);
```

Description

[2] The `wcscspn` function computes the length of the maximum initial segment of the wide string pointed to by `s1` which consists entirely of wide characters *not* from the wide string pointed to by `s2`.

Returns

[3] The `wcscspn` function returns the length of the segment.

7.17.4.5.3 The `wcspbrk` function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wcspbrk(const wchar_t *s1, const wchar_t *s2);
```

Description

[2] The `wcspbrk` function locates the first occurrence in the wide string pointed to by `s1` of any wide character from the wide string pointed to by `s2`.

Returns

[3] The **wcspbrk** function returns a pointer to the wide character in **s1**, or a null pointer if no wide character from **s2** occurs in **s1**.

7.17.4.5.4 The wcsrchr function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wcsrchr(const wchar_t *s, wchar_t c);
```

Description

[2] The **wcsrchr** function locates the last occurrence of **c** in the wide string pointed to by **s**. The terminating null wide character is considered to be part of the wide string.

Returns

[3] The **wcsrchr** function returns a pointer to the wide character, or a null pointer if **c** does not occur in the wide string.

7.17.4.5.5 The wcsspn function

Synopsis

[1]

```
#include <wchar.h>
size_t wcsspn(const wchar_t *s1, const wchar_t *s2);
```

Description

[2] The **wcsspn** function computes the length of the maximum initial segment of the wide string pointed to by **s1** which consists entirely of wide characters from the wide string pointed to by **s2**.

Returns

[3] The **wcsspn** function returns the length of the segment.

7.17.4.5.6 The wcsstr function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wcsstr(const wchar_t *s1, const wchar_t *s2);
```

Description

[2] The **wcsstr** function locates the first occurrence in the wide string pointed to by **s1** of the sequence of wide characters (excluding the terminating null wide character) in the wide string pointed to by **s2**.

Returns

[3] The **wcsstr** function returns a pointer to the located wide string, or a null pointer if the wide string is not found. If **s2** points to a wide string with zero length, the function returns **s1**.

7.17.4.5.7 The wcstok function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wcstok(wchar_t * restrict s1,
     const wchar_t * restrict s2,
     wchar_t ** restrict ptr);
```

Description

[2] A sequence of calls to the **wcstok** function breaks the wide string pointed to by **s1** into a sequence of tokens, each of which is delimited by a wide character from the wide string pointed to by **s2**. The third argument points to a caller-provided **wchar_t** pointer into which the **wcstok** function stores information necessary for it to continue scanning the same wide string.

[3] For the first call in the sequence, **s1** shall point to a wide string, while in subsequent calls for the same string, **s1** shall be a null pointer. If **s1** is a null pointer, the value pointed to by **ptr** shall match that stored by the previous call for the same wide string; otherwise the value pointed to by **ptr** is ignored. The separator wide string pointed to by **s2** may be different from call to call.

[4] The first call in the sequence searches the wide string pointed to by **s1** for the first wide character that is *not* contained in the current separator wide string pointed to by **s2**. If no such wide character is found, then there are no tokens in the wide string pointed to by **s1** and the **wcstok** function returns a null pointer. If such a wide character is found, it is the start of the first token.

[5] The **wcstok** function then searches from there for a wide character that *is* contained in the current separator wide string. If no such wide character is found, the current token extends to the end of the wide string pointed to by **s1**, and subsequent searches in the same wide string for a token return a null pointer. If such a wide character is found, it is overwritten by a null wide character, which terminates the current token.

[6] In all cases, the **wcstok** function stores sufficient information in the pointer pointed to by **ptr** so that subsequent calls, with a null pointer for **s1** and the unmodified pointer value for **ptr**, shall start searching just past the element overwritten by a null wide character (if any).

Returns

[7] The **wcstok** function returns a pointer to the first wide character of a token, or a null pointer if there is no token.

Example

```
#include <wchar.h>
static wchar_t str1[] = L"?a???b,,,#c";
static wchar_t str2[] = L"\t \t";
wchar_t *t, *ptr1, *ptr2;

/* t points to the token L"a" */
t = wcstok(str1, L"?", &ptr1);

/* t points to the token L"??b" */
t = wcstok(NULL, L",", &ptr1);

/* t is a null pointer */
t = wcstok(str2, L" \t", &ptr2);

/* t points to the token L"c" */
t = wcstok(NULL, L"#,", &ptr1);

/* t is a null pointer */
t = wcstok(NULL, L"?", &ptr1);
```

7.17.4.5.8 The `wcslen` function

Synopsis

[1]

```
#include <wchar.h>
size_t wcslen(const wchar_t *s);
```

Description

[2] The **`wcslen`** function computes the length of the wide string pointed to by **`s`**.

Returns

[3] The **`wcslen`** function returns the number of wide characters that precede the terminating null wide character.

7.17.4.6 Wide-character array functions

[1] These functions operate on arrays of type **`wchar_t`** whose size is specified by a separate count argument. These functions are not affected by locale and all **`wchar_t`** values are treated identically. The null wide character and **`wchar_t`** values not corresponding to valid multibyte characters are not treated specially.

[2] Unless explicitly stated otherwise, the functions described in this subclause order two wide characters the same way as two integers of the underlying integral type designated by **`wchar_t`**.

[3] Where an argument declared as **size_t n** determines the length of the array for a function, **n** can have the value zero on a call to that function. Unless stated explicitly otherwise in the description of a particular function in this subclause, pointer arguments on such a call must still have valid values, as described in subclause 7.1.7. On such a call, a function that locates a wide character finds no occurrence, a function that compares two wide character sequences returns zero, and a function that copies wide characters copies zero wide characters.

7.17.4.6.1 The wmemchr function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wmemchr(const wchar_t *s, wchar_t c,
     size_t n);
```

Description

[2] The **wmemchr** function locates the first occurrence of **c** in the initial **n** wide characters of the object pointed to by **s**.

Returns

[3] The **wmemchr** function returns a pointer to the located wide character, or a null pointer if the wide character does not occur in the object.

7.17.4.6.2 The wmemcmp function

Synopsis

[1]

```
#include <wchar.h>
int wmemcmp(const wchar_t *s1, const wchar_t *s2,
     size_t n);
```

Description

[2] The **wmemcmp** function compares the first **n** wide characters of the object pointed to by **s1** to the first **n** wide characters of the object pointed to by **s2**.

Returns

[3] The **wmemcmp** function returns an integer greater than, equal to, or less than zero, accordingly as the object pointed to by **s1** is greater than, equal to, or less than the object pointed to by **s2**.

7.17.4.6.3 The wmemcpy function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wmemcpy(wchar_t * restrict s1,
     const wchar_t * restrict s2,
     size_t n);
```

Description

[2] The **wmemcpy** function copies **n** wide characters from the object pointed to by **s2** to the object pointed to by **s1**.

Returns

[3] The **wmemcpy** function returns the value of **s1**.

7.17.4.6.4 The wmemmove function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wmemmove(wchar_t *s1, const wchar_t *s2,
     size_t n);
```

Description

[2] The **wmemmove** function copies **n** wide characters from the object pointed to by **s2** to the object pointed to by **s1**. Copying takes place as if the **n** wide characters from the object pointed to by **s2** are first copied into a temporary array of **n** wide characters that does not overlap the objects pointed to by **s1** or **s2**, and then the **n** wide characters from the temporary array are copied into the object pointed to by **s1**.

Returns

[3] The **wmemmove** function returns the value of **s1**.

7.17.4.6.5 The wmemset function

Synopsis

[1]

```
#include <wchar.h>
wchar_t *wmemset(wchar_t *s, wchar_t c, size_t n);
```

Description

[2] The **wmemset** function copies the value of **c** into each of the first **n** wide characters of the object pointed to by **s**.

Returns

[3] The **wmemset** function returns the value of **s**.

7.17.5 The `wcsftime` function

Synopsis

[1]

```
#include <wchar.h>
size_t wcsftime(wchar_t * restrict s,
     size_t maxsize,
     const wchar_t * restrict format,
     const struct tm * restrict timeptr);
```

Description

[2] The **wcsftime** function is equivalent to the **strftime** function, except that:

- The argument **s** points to the initial element of an array of wide characters into which the generated output is to be placed.
- The argument **maxsize** indicates the limiting number of wide characters.
- The argument **format** is a wide string and the conversion specifiers are replaced by corresponding sequences of wide characters.
- The return value indicates the number of wide characters.

Returns

[3] If the total number of resulting wide characters including the terminating null wide character is not more than **maxsize**, the **wcsftime** function returns the number of wide characters placed into the array pointed to by **s** not including the terminating null wide character. Otherwise, zero is returned and the contents of the array are indeterminate.

7.17.6 Extended multibyte and wide-character conversion utilities

[1] The header **<wchar.h>** declares an extended set of functions useful for conversion between multibyte characters and wide characters.

[2] Most of the following functions — those that are listed as ‘‘restartable’’, subclauses 7.17.6.3 and 7.17.6.4 — take as a last argument a pointer to an object of type **mbstate_t** that is used to describe the current *conversion state* from a particular multibyte character sequence to a wide-character sequence (or the reverse) under the rules of a particular setting for the **LC_CTYPE** category of the current locale.

[3] The initial conversion state corresponds, for a conversion in either direction, to the beginning of a new multibyte character in the initial shift state. A zero-valued **mbstate_t** object is (at least) one way to describe an initial conversion state. A zero-valued **mbstate_t** object can be used to initiate conversion involving any multibyte character sequence, in any **LC_CTYPE** category setting. If an **mbstate_t** object has been altered by any of the functions described in this subclause, and is then used with a different multibyte character sequence, or in the other conversion direction, or with a different **`LC_CTYPE`** category setting than on earlier function calls, the behavior is undefined.[199]

[4] On entry, each function takes the described conversion state (either internal or pointed to by **`ps`**) as current. The conversion state described by the pointed-to object is altered as needed to track the shift state, and the position within a multibyte character, for the associated multibyte character sequence.

7.17.6.1 Single-byte wide-character conversion functions

7.17.6.1.1 The `btowc` function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
wint_t btowc(int c);
```

Description

[2] The **`btowc`** function determines whether **`c`** constitutes a valid (one-byte) multibyte character in the initial shift state.

Returns

[3] The **`btowc`** returns **`WEOF`** if **`c`** has the value **`EOF`** or if **`(unsigned char)c`** does not constitute a valid (one-byte) multibyte character in the initial shift state. Otherwise, it returns the wide-character representation of that character.

7.17.6.1.2 The `wctob` function

Synopsis

[1]

```
#include <stdio.h>
#include <wchar.h>
int wctob(wint_t c);
```

Description

[2] The **`wctob`** function determines whether **`c`** corresponds to a member of the extended character set whose multibyte character representation is a single byte when in the initial shift state.

Returns

199. Thus a particular **`mbstate_t`** object can be used, for example, with both the **`mbrtowc`** and **`mbsrtowcs`** functions as long as they are used to step sequentially through the same multibyte character string.

[3] The **`wctob`** returns **`EOF`** if **`c`** does not correspond to a multibyte character with length one in the initial shift state. Otherwise, it returns the single-byte representation of that character.

7.17.6.2 The `mbsinit` function

Synopsis

[1]

```
#include <wchar.h>
int mbsinit(const mbstate_t *ps);
```

Description

[2] If **`ps`** is not a null pointer, the **`mbsinit`** function determines whether the pointed-to **`mbstate_t`** object describes an initial conversion state.

Returns

[3] The **`mbsinit`** function returns nonzero if **`ps`** is a null pointer or if the pointed-to object describes an initial conversion state; otherwise, it returns zero.

7.17.6.3 Restartable multibyte/wide-character conversion functions

[1] These functions differ from the corresponding multibyte character functions of subclause 7.12.7 (**`mblen`**, **`mbtowc`**, and **`wctomb`**) in that they have an extra parameter, **`ps`**, of type pointer to **`mbstate_t`** that points to an object that can completely describe the current conversion state of the associated multibyte character sequence. If **`ps`** is a null pointer, each function uses its own internal **`mbstate_t`** object instead, which is initialized at program startup to the initial conversion state. The implementation behaves as if no library function calls these functions with a null pointer for **`ps`**.

[2] Also unlike their corresponding functions, the return value does not represent whether the encoding is state-dependent.

7.17.6.3.1 The `mbrlen` function

Synopsis

[1]

```
#include <wchar.h>
size_t mbrlen(const char * restrict s,
     size_t n,
     mbstate_t * restrict ps);
```

Description

[2] The **`mbrlen`** function is equivalent to the call:

```
mbrtowc(NULL, s, n, ps != NULL ? ps : &internal)
```

[3] where **internal** is the **mbstate_t** object for the **mbrlen** function.

Returns

[4] The **mbrlen** function returns **(size_t)-2**, **(size_t)-1**, a value between zero and **n**, inclusive.

[5] Forward References: the **mbrtowc** function (7.17.6.3.2).

7.17.6.3.2 The mbrtowc function

Synopsis

[1]

```
#include <wchar.h>
size_t mbrtowc(wchar_t * restrict pwc,
     const char * restrict s,
     size_t n,
     mbstate_t * restrict ps);
```

Description

[2] If **s** is a null pointer, the **mbrtowc** function is equivalent to the call:

```
mbrtowc(NULL, "", 1, ps)
```

[3] In this case, the values of the parameters **pwc** and **n** are ignored.

[4] If **s** is not a null pointer, the **mbrtowc** function inspects at most **n** bytes beginning with the byte pointed to by **s** to determine the number of bytes needed to complete the next multibyte character (including any shift sequences). If the function determines that the next multibyte character is completed, it determines the value of the corresponding wide character and then, if **pwc** is not a null pointer, stores that value in the object pointed to by **pwc**. If the corresponding wide character is the null wide character, the resulting state described is the initial conversion state.

Returns

[5] The **mbrtowc** function returns the first of the following that applies (given the current conversion state):

0 — if the next **n** or fewer bytes complete the multibyte character that corresponds to the null wide character (which is the value stored).

positive — if the next **n** or fewer bytes complete a valid multibyte character (which is the value stored), the value returned is the number of bytes that complete the multibyte character.

(size_t)-2 — if the next **n** bytes contribute to an incomplete (but potentially valid) multibyte character, and all **n** bytes have been processed (no value is stored).[200]

(size_t)-1 if an encoding error occurs, in which case the next **n** or fewer bytes do not contribute to a complete and valid multibyte character (no value is stored); the value of the macro **EILSEQ** is stored in **errno**, and the conversion state is undefined.

7.17.6.3.3 The wcrtomb function

Synopsis

[1]

```
#include <wchar.h>
size_t wcrtomb(char * restrict s,
     wchar_t wc,
     mbstate_t * restrict ps);
```

Description

[2] If **s** is a null pointer, the **wcrtomb** function is equivalent to the call

```
wcrtomb(buf, L'\0', ps)
```

[3] where ***buf*** is an internal buffer.

[4] If **s** is not a null pointer, the **wcrtomb** function determines the number of bytes needed to represent the multibyte character that corresponds to the wide character given by **wc** (including any shift sequences), and stores the resulting bytes in the array whose first element is pointed to by **s**. At most **MB_CUR_MAX** bytes are stored. If **wc** is a null wide character, a null byte is stored, preceded by any shift sequence needed to restore the initial shift state; the resulting state described is the initial conversion state.

Returns

[5] The **wcrtomb** function returns the number of bytes stored in the array object (including any shift sequences). When **wc** is not a valid wide character, an encoding error occurs: the function stores the value of the macro **EILSEQ** in **errno** and returns **(size_t)-1**; the conversion state is undefined.

200. When **n** has at least the value of the **MB_CUR_MAX** macro, this case can only occur if **s** points at a sequence of redundant shift sequences (for implementations with state-dependent encodings).

7.17.6.4 Restartable multibyte/wide-string conversion functions

[1] These functions differ from the corresponding multibyte string functions of subclause 7.12.8 (**`mbstowcs`** and **`wcstombs`**) in that they have an extra parameter, **`ps`**, of type pointer to **`mbstate_t`** that points to an object that can completely describe the current conversion state of the associated multibyte character sequence. If **`ps`** is a null pointer, each function uses its own internal **`mbstate_t`** object instead, which is initialized at program startup to the initial conversion state. The implementation behaves as if no library function calls these functions with a null pointer for **`ps`**.

[2] Also unlike their corresponding functions, the conversion source parameter, **`src`**, has a pointer-to-pointer type. When the function is storing the results of conversions (that is, when **`dst`** is not a null pointer), the pointer object pointed to by this parameter is updated to reflect the amount of the source processed by that invocation.

7.17.6.4.1 The `mbsrtowcs` function

Synopsis

[1]

```
#include <wchar.h>
size_t mbsrtowcs(wchar_t * restrict dst,
     const char ** restrict src,
     size_t len,
     mbstate_t * restrict ps);
```

Description

[2] The **`mbsrtowcs`** function converts a sequence of multibyte characters, beginning in the conversion state described by the object pointed to by **`ps`**, from the array indirectly pointed to by **`src`** into a sequence of corresponding wide characters. If **`dst`** is not a null pointer, the converted characters are stored into the array pointed to by **`dst`**. Conversion continues up to and including a terminating null character, which is also stored. Conversion stops earlier in two cases: when a sequence of bytes is encountered that does not form a valid multibyte character, or (if **`dst`** is not a null pointer) when **`len`** codes have been stored into the array pointed to by **`dst`**.[201] Each conversion takes place as if by a call to the **`mbrtowc`** function.

[3] If **`dst`** is not a null pointer, the pointer object pointed to by **`src`** is assigned either a null pointer (if conversion stopped due to reaching a terminating null character) or the address just past the last multibyte character converted (if any). If conversion stopped due to reaching a terminating null character and if **`dst`** is not a null pointer, the resulting state described is the initial conversion state.

---

201. Thus, the value of **`len`** is ignored if **`dst`** is a null pointer.

Returns

[4] If the input conversion encounters a sequence of bytes that do not form a valid multibyte character, an encoding error occurs: the **`mbsrtowcs`** function stores the value of the macro **`EILSEQ`** in **`errno`** and returns **`(size_t)-1`**; the conversion state is undefined. Otherwise, it returns the number of multibyte characters successfully converted, not including the terminating null (if any).

7.17.6.4.2 The `wcsrtombs` function

Synopsis

[1]

```
#include <wchar.h>
size_t wcsrtombs(char * restrict dst,
     const wchar_t ** restrict src,
     size_t len,
     mbstate_t * restrict ps);
```

Description

[2] The **`wcsrtombs`** function converts a sequence of wide characters from the array indirectly pointed to by **`src`** into a sequence of corresponding multibyte characters, beginning in the conversion state described by the object pointed to by **`ps`**. If **`dst`** is not a null pointer, the converted characters are then stored into the array pointed to by **`dst`**. Conversion continues up to and including a terminating null wide character, which is also stored. Conversion stops earlier in two cases: when a code is reached that does not correspond to a valid multibyte character, or (if **`dst`** is not a null pointer) when the next multibyte character would exceed the limit of **`len`** total bytes to be stored into the array pointed to by **`dst`**. Each conversion takes place as if by a call to the **`wcrtomb`** function.[202]

[3] If **`dst`** is not a null pointer, the pointer object pointed to by **`src`** is assigned either a null pointer (if conversion stopped due to reaching a terminating null wide character) or the address just past the last wide character converted (if any). If conversion stopped due to reaching a terminating null wide character, the resulting state described is the initial conversion state.

Returns

[4] If conversion stops because a code is reached that does not correspond to a valid multibyte character, an encoding error occurs: the **`wcsrtombs`** function stores the value of the macro **`EILSEQ`** in **`errno`** and returns **`(size_t)-1`**; the conversion

202. If conversion stops because a terminating null wide character has been reached, the bytes stored include those necessary to reach the initial shift state immediately before the null byte.

state is undefined. Otherwise, it returns the number of bytes in the resulting multibyte character sequence, not including the terminating null (if any).

7.18 Future library directions

[1] The following names are grouped under individual headers for convenience. All external names described below are reserved no matter what headers are included by the program.

7.18.1 Errors `<errno.h>`

[1] Macros that begin with `E` and a digit or `E` and an uppercase letter (followed by any combination of digits, letters, and underscore) may be added to the declarations in the `<errno.h>` header.

7.18.2 Character handling `<ctype.h>`

[1] Function names that begin with either `is` or `to`, and a lowercase letter (followed by any combination of digits, letters, and underscore) may be added to the declarations in the `<ctype.h>` header.

7.18.3 Localization `<locale.h>`

[1] Macros that begin with `LC_` and an uppercase letter (followed by any combination of digits, letters, and underscore) may be added to the definitions in the `<locale.h>` header.

7.18.4 Mathematics `<math.h>`

[1] The names of all existing functions declared in the `<math.h>` header, suffixed with `f` or `l`, are reserved respectively for corresponding functions with `float` and `long double` arguments and return values.

7.18.5 Signal handling `<signal.h>`

[1] Macros that begin with either `SIG` and an uppercase letter or `SIG_` and an uppercase letter (followed by any combination of digits, letters, and underscore) may be added to the definitions in the `<signal.h>` header.

7.18.6 Input/output `<stdio.h>`

[1] Lowercase letters may be added to the conversion specifiers in `fprintf` and `fscanf`. Other characters may be used in extensions.

7.18.7 General utilities `<stdlib.h>`

[1] Function names that begin with `str` and a lowercase letter (followed by any combination of digits, letters, and underscore) may be added to the declarations in the `<stdlib.h>` header.

7.18.8 String handling `<string.h>`

[1] Function names that begin with **`str`**, **`mem`**, or **`wcs`** and a lowercase letter (followed by any combination of digits, letters, and underscore) may be added to the declarations in the **`<string.h>`** header.

7.18.9 Wide-character classification and mapping utilities `<wctype.h>`

[1] Function names that begin with **`is`** or **`to`** and a lowercase letter (followed by any combination of digits, letters, and underscore) may be added to the declarations in the **`<wctype.h>`** header.

7.18.10 Extended multibyte and wide-character utilities `<wchar.h>`

[1] Function names that begin with **`wcs`** and a lowercase letter (followed by any combination of digits, letters, and underscore) may be added to the declarations in the **`<wchar.h>`** header.

[2] Lowercase letters may be added to the conversion specifiers in **`fwprintf`** and **`fwscanf`**.

Annex A
(informative)
Bibliography

1. ‘‘The C Reference Manual’’ by Dennis M. Ritchie, a version of which was published in *The C Programming Language* by Brian W. Kernighan and Dennis M. Ritchie, Prentice-Hall, Inc., (1978). Copyright owned by AT&T.

2. *1984 /usr/group Standard* by the /usr/group Standards Committee, Santa Clara, California, USA, November 1984.

3. ANSI X3/TR-1-82 (1982), *American National Dictionary for Information Processing Systems*, Information Processing Systems Technical Report.

4. ANSI/IEEE 754-1985, *American National Standard for Binary Floating-Point Arithmetic*.

Annex B
(informative)
Language syntax summary

[1] Note — The notation is described in the introduction to clause 3 (Language).

B.1 Lexical grammar

[1] [**Editor: The following grammar need to be updated.**]

B.1.1 Tokens

(6.1) *token:*
keyword
identifier
constant
string-literal
operator
punctuator

(6.1) *preprocessing-token:*
header-name
identifier
pp-number
character-constant
string-literal
operator
punctuator
each non-white-space character that cannot be one of the above

B.1.2 Keywords

(6.1.1) *keyword:* one of

```
auto      double  int      struct
break     else    long     switch
case      enum    register typedef
char      extern  return   union
const     float   short    unsigned
continue  for     signed   void
default   goto    sizeof   volatile
do        if      static   while
```

B.1.3 Identifiers

(6.1.2) *identifier:*

nondigit
identifier nondigit
identifier digit

(6.1.2) *nondigit:* one of

`_ a b c d e f g h i j k l m`
`n o p q r s t u v w x y z`
`A B C D E F G H I J K L M`
`N O P Q R S T U V W X Y Z`

(6.1.2) *digit:* one of

`0 1 2 3 4 5 6 7 8 9`

B.1.4 Constants

(6.1.3) *constant:*

floating-constant
integer-constant
enumeration-constant
character-constant

(6.1.3.1) *floating-constant:*

fractional-constant exponent-part$_{opt}$ *floating-suffix*$_{opt}$
digit-sequence exponent-part floating-suffix$_{opt}$

(6.1.3.1) *fractional-constant:*

digit-sequence$_{opt}$ **`.`** *digit-sequence*
digit-sequence **`.`**

(6.1.3.1) *exponent-part:*

`e` *sign*$_{opt}$ *digit-sequence*
`E` *sign*$_{opt}$ *digit-sequence*

(6.1.3.1) *sign:* one of

`+ -`

(6.1.3.1) *digit-sequence:*

digit
digit-sequence digit

(6.1.3.1) *floating-suffix:* one of

`f l F L`

(6.1.3.2) *integer-constant:*

decimal-constant integer-suffix$_{opt}$
octal-constant integer-suffix$_{opt}$
hexadecimal-constant integer-suffix$_{opt}$

(6.1.3.2) *decimal-constant:*
nonzero-digit
decimal-constant digit

(6.1.3.2) *octal-constant:*
0
octal-constant octal-digit

(6.1.3.2) *hexadecimal-constant:*
0x *hexadecimal-digit*
0X *hexadecimal-digit*
hexadecimal-constant hexadecimal-digit

(6.1.3.2) *nonzero-digit:* one of
1 2 3 4 5 6 7 8 9

(6.1.3.2) *octal-digit:* one of
0 1 2 3 4 5 6 7

(6.1.3.2) *hexadecimal-digit:* one of
0 1 2 3 4 5 6 7 8 9
a b c d e f
A B C D E F

(6.1.3.2) *integer-suffix:*
unsigned-suffix long-suffix$_{opt}$
long-suffix unsigned-suffix$_{opt}$

(6.1.3.2) *unsigned-suffix:* one of
u U

(6.1.3.2) *long-suffix:* one of
l L

(6.1.3.3) *enumeration-constant:*
identifier

(6.1.3.4) *character-constant:*
'*c-char-sequence***'**
L'*c-char-sequence***'**

(6.1.3.4) *c-char-sequence:*
c-char
c-char-sequence c-char

(6.1.3.4) *c-char:*
any member of the source character set except
the single-quote **'**, backslash ****, or new-line character
escape-sequence

(6.1.3.4) *escape-sequence:*
simple-escape-sequence
octal-escape-sequence
hexadecimal-escape-sequence

(6.1.3.4) *simple-escape-sequence:* one of
**\' \" \? **
\a \b \f \n \r \t \v

(6.1.3.4) *octal-escape-sequence:*
**** *octal-digit*
**** *octal-digit octal-digit*
**** *octal-digit octal-digit octal-digit*

(6.1.3.4) *hexadecimal-escape-sequence:*
\x *hexadecimal-digit*
hexadecimal-escape-sequence hexadecimal-digit

B.1.5 String literals

(6.1.4) *string-literal:*
"*s-char-sequence*$_{opt}$**"**
L"*s-char-sequence*$_{opt}$**"**

(6.1.4) *s-char-sequence:*
s-char
s-char-sequence s-char

(6.1.4) *s-char:*
any member of the source character set except
the double-quote **"**, backslash ****, or new-line character
escape-sequence

B.1.6 Operators

(6.1.5) *operator:* one of

```
[  ]  (  )  .  ->
++  --  &  *  +  -  ~  !  sizeof
/  %  <<  >>  <  >  <=  >=  ==  !=  ^  |  &&  ||
?  :
=  *=  /=  %=  +=  -=  <<=  >>=  &=  ^=  |=
,  #  ##
```

B.1.7 Punctuators

(6.1.6) *punctuator:* one of

[ ] ( ) { } * , : = ; ... #

B.1.8 Header names

(6.1.7) *header-name:*

<*h-char-sequence*>
"*q-char-sequence*"

(6.1.7) *h-char-sequence:*

h-char
h-char-sequence h-char

(6.1.7) *h-char:*

any member of the source character set except the new-line character and **>**

(6.1.7) *q-char-sequence:*

q-char
q-char-sequence q-char

(6.1.7) *q-char:*

any member of the source character set except the new-line character and **"**

B.1.9 Preprocessing numbers

(6.1.8) *pp-number:*

digit
. *digit*
pp-number digit
pp-number nondigit
pp-number **e** *sign*
pp-number **E** *sign*
pp-number **.**

B.2 Phrase structure grammar

B.2.1 Expressions

(6.3.1) *primary-expression:*
identifier
constant
string-literal
(*expression* **)**

(6.3.2) *postfix-expression:*
primary-expression
postfix-expression **[** *expression* **]**
postfix-expression **(** *argument-expression-list*$_{opt}$ **)**
postfix-expression **.** *identifier*
postfix-expression **->** *identifier*
postfix-expression **++**
postfix-expression **--**

(6.3.2) *argument-expression-list:*
assignment-expression
argument-expression-list **,** *assignment-expression*

(6.3.3) *unary-expression:*
postfix-expression
++ *unary-expression*
-- *unary-expression*
unary-operator cast-expression
sizeof *unary-expression*
sizeof (*type-name* **)**

(6.3.3) *unary-operator:* one of
& * + - ~ !

(6.3.4) *cast-expression:*
unary-expression
(*type-name* **)** *cast-expression*

(6.3.5) *multiplicative-expression:*
cast-expression
multiplicative-expression ***** *cast-expression*
multiplicative-expression **/** *cast-expression*
multiplicative-expression **%** *cast-expression*

(6.3.6) *additive-expression:*
multiplicative-expression
additive-expression **+** *multiplicative-expression*
additive-expression **-** *multiplicative-expression*

(6.3.7) *shift-expression:*
additive-expression
shift-expression **<<** *additive-expression*
shift-expression **>>** *additive-expression*

(6.3.8) *relational-expression:*
shift-expression
relational-expression **<** *shift-expression*
relational-expression **>** *shift-expression*
relational-expression **<=** *shift-expression*
relational-expression **>=** *shift-expression*

(6.3.9) *equality-expression:*
relational-expression
equality-expression **==** *relational-expression*
equality-expression **!=** *relational-expression*

(6.3.10) *AND-expression:*
equality-expression
AND-expression **&** *equality-expression*

(6.3.11) *exclusive-OR-expression:*
AND-expression
exclusive-OR-expression **^** *AND-expression*

(6.3.12) *inclusive-OR-expression:*
exclusive-OR-expression
inclusive-OR-expression **|** *exclusive-OR-expression*

(6.3.13) *logical-AND-expression:*
inclusive-OR-expression
logical-AND-expression **&&** *inclusive-OR-expression*

(6.3.14) *logical-OR-expression:*
logical-AND-expression
logical-OR-expression **||** *logical-AND-expression*

(6.3.15) *conditional-expression:*
logical-OR-expression
logical-OR-expression **?** *expression* **:** *conditional-expression*

(6.3.16) *assignment-expression:*
conditional-expression
unary-expression assignment-operator assignment-expression

(6.3.16) *assignment-operator:* one of
= *= /= %= += -= <<= >>= &= ^= |=

(6.3.17) *expression:*
assignment-expression
expression **,** *assignment-expression*

(6.4) *constant-expression:*
conditional-expression

B.2.2 Declarations

(6.5) *declaration:*
declaration-specifiers *init-declarator-list*$_{opt}$ **;**

(6.5) *declaration-specifiers:*
storage-class-specifier *declaration-specifiers*$_{opt}$
type-specifier *declaration-specifiers*$_{opt}$
type-qualifier *declaration-specifiers*$_{opt}$

(6.5) *init-declarator-list:*
init-declarator
init-declarator-list **,** *init-declarator*

(6.5) *init-declarator:*
declarator
declarator **=** *initializer*

(6.5.1) *storage-class-specifier:*
typedef
extern
static
auto
register

(6.5.2) *type-specifier:*
void
char
short
int
long
float
double
signed
unsigned
struct-or-union-specifier
enum-specifier
typedef-name

(6.5.2.1) *struct-or-union-specifier:*
struct-or-union *identifier*$_{opt}$ **{** *struct-declaration-list* **}**
struct-or-union *identifier*

(6.5.2.1) *struct-or-union:*
`struct`
`union`

(6.5.2.1) *struct-declaration-list:*
struct-declaration
struct-declaration-list struct-declaration

(6.5.2.1) *struct-declaration:*
specifier-qualifier-list struct-declarator-list **`;`**

(6.5.2.1) *specifier-qualifier-list:*
type-specifier specifier-qualifier-list$_{opt}$
type-qualifier specifier-qualifier-list$_{opt}$

(6.5.2.1) *struct-declarator-list:*
struct-declarator
struct-declarator-list **`,`** *struct-declarator*

(6.5.2.1) *struct-declarator:*
declarator
declarator$_{opt}$ **`:`** *constant-expression*

(6.5.2.2) *enum-specifier:*
`enum` *identifier*$_{opt}$ **`{`** *enumerator-list* **`}`**
`enum` *identifier*

(6.5.2.2) *enumerator-list:*
enumerator
enumerator-list **`,`** *enumerator*

(6.5.2.2) *enumerator:*
enumeration-constant
enumeration-constant **`=`** *constant-expression*

(6.5.3) *type-qualifier:*
`const`
`volatile`

(6.5.4) *declarator:*
pointer$_{opt}$ *direct-declarator*

(6.5.4) *direct-declarator:*
identifier
`(` *declarator* **`)`**
direct-declarator **`[`** *constant-expression*$_{opt}$ **`]`**
direct-declarator **`(`** *parameter-type-list* **`)`**
direct-declarator **`(`** *identifier-list*$_{opt}$ **`)`**

(6.5.4) *pointer:*
  ***** *type-qualifier-list*$_{opt}$
  ***** *type-qualifier-list*$_{opt}$ *pointer*

(6.5.4) *type-qualifier-list:*
  type-qualifier
  type-qualifier-list type-qualifier

(6.5.4) *parameter-type-list:*
  parameter-list
  parameter-list **, ...**

(6.5.4) *parameter-list:*
  parameter-declaration
  parameter-list **,** *parameter-declaration*

(6.5.4) *parameter-declaration:*
  declaration-specifiers declarator
  declaration-specifiers abstract-declarator$_{opt}$

(6.5.4) *identifier-list:*
  identifier
  identifier-list **,** *identifier*

(6.5.5) *type-name:*
  specifier-qualifier-list abstract-declarator$_{opt}$

(6.5.5) *abstract-declarator:*
  pointer
  pointer$_{opt}$ *direct-abstract-declarator*

(6.5.5) *direct-abstract-declarator:*
  (*abstract-declarator* **)**
  direct-abstract-declarator$_{opt}$ **[** *constant-expression*$_{opt}$ **]**
  direct-abstract-declarator$_{opt}$ **(** *parameter-type-list*$_{opt}$ **)**

(6.5.6) *typedef-name:*
  identifier

(6.5.7) *initializer:*
  assignment-expression
  { *initializer-list* **}**
  { *initializer-list* **, }**

(6.5.7) *initializer-list:*
  initializer
  initializer-list **,** *initializer*

B.2.3 Statements

(6.6) *statement:*
  labeled-statement
  compound-statement
  expression-statement
  selection-statement
  iteration-statement
  jump-statement

(6.6.1) *labeled-statement:*
  identifier **:** *statement*
  case *constant-expression* **:** *statement*
  default : *statement*

(6.6.2) *compound-statement:*
  { *declaration-list*$_{opt}$ *statement-list*$_{opt}$ **}**

(6.6.2) *declaration-list:*
  declaration
  declaration-list declaration

(6.6.2) *statement-list:*
  statement
  statement-list statement

(6.6.3) *expression-statement:*
  expression$_{opt}$ **;**

(6.6.4) *selection-statement:*
  if (*expression* **)** *statement*
  if (*expression* **)** *statement* **else** *statement*
  switch (*expression* **)** *statement*

(6.6.5) *iteration-statement:*
  while (*expression* **)** *statement*
  do *statement* **while (** *expression* **) ;**
  for (*expression*$_{opt}$ **;** *expression*$_{opt}$ **;** *expression*$_{opt}$ **)** *statement*

(6.6.6) *jump-statement:*
  goto *identifier* **;**
  continue ;
  break ;
  return *expression*$_{opt}$ **;**

B.2.4 External definitions

(6.7) *translation-unit:*
external-declaration
translation-unit external-declaration

(6.7) *external-declaration:*
function-definition
declaration

(6.7.1) *function-definition:*
declaration-specifiers$_{opt}$ *declarator* *declaration-list*$_{opt}$ *compound-statement*

B.3 Preprocessing directives

(6.8) *preprocessing-file:*
group$_{opt}$

(6.8) *group:*
group-part
group group-part

(6.8) *group-part:*
pp-tokens$_{opt}$ *new-line*
if-section
control-line

(6.8.1) *if-section:*
if-group *elif-groups*$_{opt}$ *else-group*$_{opt}$ *endif-line*

(6.8.1) *if-group:*
`# if` *constant-expression new-line group*$_{opt}$
`# ifdef` *identifier new-line group*$_{opt}$
`# ifndef` *identifier new-line group*$_{opt}$

(6.8.1) *elif-groups:*
elif-group
elif-groups elif-group

(6.8.1) *elif-group:*
`# elif` *constant-expression new-line group*$_{opt}$

(6.8.1) *else-group:*
`# else` *new-line group*$_{opt}$

(6.8.1) *endif-line:*
`# endif` *new-line*

control-line:
(6.8.2) **# include** *pp-tokens new-line*
(6.8.3) **# define** *identifier replacement-list new-line*
(6.8.3) **# define** *identifier lparen identifier-list*$_{opt}$ **)** *replacement-list new-line*
(6.8.3) **# undef** *identifier new-line*
(6.8.4) **# line** *pp-tokens new-line*
(6.8.5) **# error** *pp-tokens*$_{opt}$ *new-line*
(6.8.6) **# pragma** *pp-tokens*$_{opt}$ *new-line*
(6.8.7) **#** *new-line*

(6.8.3) *lparen:*
the left-parenthesis character without preceding white space

(6.8.3) *replacement-list:*
pp-tokens$_{opt}$

(6.8) *pp-tokens:*
preprocessing-token
pp-tokens preprocessing-token

(6.8) *new-line:*
the new-line character

Annex C
(informative)
Sequence points

[1] The following are the sequence points described in 5.1.2.3.

[2]

— The call to a function, after the arguments have been evaluated (6.3.2.2).

— The end of the first operand of the following operators: logical AND **`&&`** (6.3.13); logical OR **`||`** (6.3.14); conditional **`?`** (6.3.15); comma **`,`** (6.3.17).

— The end of a full expression: an initializer (6.5.7); the expression in an expression statement (6.6.3); the controlling expression of a selection statement (**`if`** or **`switch`**) (6.6.4); the controlling expression of a **`while`** or **`do`** statement (6.6.5); each of the three expressions of a **`for`** statement (6.6.5.3); the expression in a **`return`** statement (6.6.6.4).

Annex D
(informative)
Library summary

[1] [**Editor: The following prototypes need to be updated.**]

D.1 Errors `<errno.h>`

```
EDOM
EILSEQ
ERANGE
errno
```

D.2 Common definitions `<stddef.h>`

```
NULL
offsetof(type, member-designator)
ptrdiff_t
size_t
wchar_t
```

D.3 Diagnostics `<assert.h>`

```
NDEBUG
void assert(int expression);
```

D.4 Character handling `<ctype.h>`

```
int isalnum(int c);
int isalpha(int c);
int iscntrl(int c);
int isdigit(int c);
int isgraph(int c);
int islower(int c);
int isprint(int c);
int ispunct(int c);
int isspace(int c);
int isupper(int c);
int isxdigit(int c);
int tolower(int c);
int toupper(int c);
```

D.5 Localization `<locale.h>`

```
LC_ALL
LC_COLLATE
LC_CTYPE
LC_MONETARY
LC_NUMERIC
LC_TIME
NULL
struct lconv
char *setlocale(int category, const char *locale);
struct lconv *localeconv(void);
```

D.6 Mathematics `<math.h>`

```
HUGE_VAL
double acos(double x);
double asin(double x);
double atan(double x);
double atan2(double y, double x);
double cos(double x);
double sin(double x);
double tan(double x);
double cosh(double x);
double sinh(double x);
double tanh(double x);
double exp(double x);
double frexp(double value, int *exp);
double ldexp(double x, int exp);
double log(double x);
double log10(double x);
double modf(double value, double *iptr);
double pow(double x, double y);
double sqrt(double x);
double ceil(double x);
double fabs(double x);
double floor(double x);
double fmod(double x, double y);
```

D.7 Nonlocal jumps `<setjmp.h>`

```
jmp_buf
int setjmp(jmp_buf env);
void longjmp(jmp_buf env, int val);
```

D.8 Signal handling `<signal.h>`

```
sig_atomic_t
SIG_DFL
SIG_ERR
SIG_IGN
SIGABRT
SIGFPE
SIGILL
SIGINT
SIGSEGV
SIGTERM
void (*signal(int sig, void (*func)(int)))(int);
int raise(int sig);
```

D.9 Variable arguments `<stdarg.h>`

```
va_list
void va_start(va_list ap, parmN);
type va_arg(va_list ap, type);
void va_end(va_list ap);
```

D.10 Input/output `<stdio.h>`

```
_IOFBF
_IOLBF
_IONBF
BUFSIZ
EOF
FILE
FILENAME_MAX
FOPEN_MAX
fpos_t
L_tmpnam
NULL
SEEK_CUR
SEEK_END
SEEK_SET
size_t
stderr
stdin
stdout
TMP_MAX
int remove(const char *filename);
int rename(const char *old, const char *new);
FILE *tmpfile(void);
char *tmpnam(char *s);
int fclose(FILE *stream);
int fflush(FILE *stream);
FILE *fopen(const char *filename, const char *mode);
FILE *freopen(const char *filename, const char *mode,
     FILE *stream);
void setbuf(FILE *stream, char *buf);
int setvbuf(FILE *stream, char *buf, int mode, size_t size);
int fprintf(FILE *stream, const char *format, ...);
int fscanf(FILE *stream, const char *format, ...);
int printf(const char *format, ...);
int scanf(const char *format, ...);
int sprintf(char *s, const char *format, ...);
int sscanf(const char *s, const char *format, ...);
int vfprintf(FILE *stream, const char *format, va_list arg);
int vprintf(const char *format, va_list arg);
```

```
int vsprintf(char *s, const char *format, va_list arg);
int fgetc(FILE *stream);
char *fgets(char *s, int n, FILE *stream);
int fputc(int c, FILE *stream);
int fputs(const char *s, FILE *stream);
int getc(FILE *stream);
int getchar(void);
char *gets(char *s);
int putc(int c, FILE *stream);
int putchar(int c);
int puts(const char *s);
int ungetc(int c, FILE *stream);
size_t fread(void *ptr, size_t size, size_t nmemb,
     FILE *stream);
size_t fwrite(const void *ptr, size_t size, size_t nmemb,
     FILE *stream);
int fgetpos(FILE *stream, fpos_t *pos);
int fseek(FILE *stream, long int offset, int whence);
int fsetpos(FILE *stream, const fpos_t *pos);
long int ftell(FILE *stream);
void rewind(FILE *stream);
void clearerr(FILE *stream);
int feof(FILE *stream);
int ferror(FILE *stream);
void perror(const char *s);
```

D.11 General utilities <stdlib.h>

```
EXIT_FAILURE
EXIT_SUCCESS
MB_CUR_MAX
NULL
RAND_MAX
div_t
ldiv_t
size_t
wchar_t
double atof(const char *nptr);
int atoi(const char *nptr);
long int atol(const char *nptr);
double strtod(const char *nptr, char **endptr);
long int strtol(const char *nptr, char **endptr, int base);
unsigned long int strtoul(const char *nptr, char **endptr,
     int base);
int rand(void);
void srand(unsigned int seed);
void *calloc(size_t nmemb, size_t size);
void free(void *ptr);
void *malloc(size_t size);
void *realloc(void *ptr, size_t size);
void abort(void);
int atexit(void (*func)(void));
void exit(int status);
char *getenv(const char *name);
int system(const char *string);
void *bsearch(const void *key, const void *base,
     size_t nmemb, size_t size,
     int (*compar)(const void *, const void *));
void qsort(void *base, size_t nmemb, size_t size,
     int (*compar)(const void *, const void *));
int abs(int j);
div_t div(int numer, int denom);
long int labs(long int j);
ldiv_t ldiv(long int numer, long int denom);
int mblen(const char *s, size_t n);
int mbtowc(wchar_t *pwc, const char *s, size_t n);
int wctomb(char *s, wchar_t wchar);
size_t mbstowcs(wchar_t *pwcs, const char *s, size_t n);
size_t wcstombs(char *s, const wchar_t *pwcs, size_t n);
```

D.12 String handling <string.h>

```
NULL
size_t
void *memcpy(void *s1, const void *s2, size_t n);
void *memmove(void *s1, const void *s2, size_t n);
char *strcpy(char *s1, const char *s2);
char *strncpy(char *s1, const char *s2, size_t n);
char *strcat(char *s1, const char *s2);
char *strncat(char *s1, const char *s2, size_t n);
int memcmp(const void *s1, const void *s2, size_t n);
int strcmp(const char *s1, const char *s2);
int strcoll(const char *s1, const char *s2);
int strncmp(const char *s1, const char *s2, size_t n);
size_t strxfrm(char *s1, const char *s2, size_t n);
void *memchr(const void *s, int c, size_t n);
char *strchr(const char *s, int c);
size_t strcspn(const char *s1, const char *s2);
char *strpbrk(const char *s1, const char *s2);
char *strrchr(const char *s, int c);
size_t strspn(const char *s1, const char *s2);
char *strstr(const char *s1, const char *s2);
char *strtok(char *s1, const char *s2);
void *memset(void *s, int c, size_t n);
char *strerror(int errnum);
size_t strlen(const char *s);
```

D.13 Date and time <time.h>

```
CLOCKS_PER_SEC
NULL
clock_t
time_t
size_t
struct tm
clock_t clock(void);
double difftime(time_t time1, time_t time0);
time_t mktime(struct tm *timeptr);
time_t time(time_t *timer);
char *asctime(const struct tm *timeptr);
char *ctime(const time_t *timer);
struct tm *gmtime(const time_t *timer);
struct tm *localtime(const time_t *timer);
size_t strftime(char *s, size_t maxsize,
     const char *format, const struct tm *timeptr);
```

D.14 Alternative spellings `<iso646.h>`

```
and
and_eq
bitand
bitor
compl
not
not_eq
or
or_eq
xor
xor_eq
```

D.15 Wide-character classification and mapping utilities `<wctype.h>`

```
wctrans_t
wctype_t
WEOF
wint_t
```

D.15.1 Wide-character classification functions

```
int iswalnum(wint_t wc);
int iswalpha(wint_t wc);
int iswcntrl(wint_t wc);
int iswdigit(wint_t wc);
int iswgraph(wint_t wc);
int iswlower(wint_t wc);
int iswprint(wint_t wc);
int iswpunct(wint_t wc);
int iswspace(wint_t wc);
int iswupper(wint_t wc);
int iswxdigit(wint_t wc);
wctype_t wctype(const char *property);
int iswctype(wint_t wc, wctype_t desc);
```

D.15.2 Wide-character mapping functions

```
wint_t towlower(wint_t wc);
wint_t towupper(wint_t wc);
wctrans_t wctrans(const char *property);
wint_t towctrans(wint_t wc, wctrans_t desc);
```

D.16 Extended multibyte and wide-character utilities `<wchar.h>`

```
mbstate_t
NULL
size_t
struct tm
wchar_t
WCHAR_MAX
WCHAR_MIN
WEOF
wint_t
```

D.16.1 Formatted wide-character input/output functions

```
int fwprintf(FILE *stream, const wchar_t *format, ...);
int fwscanf(FILE *stream, const wchar_t *format, ...);
int wprintf(const wchar_t *format, ...);
int wscanf(const wchar_t *format, ...);
int swprintf(wchar_t *s, size_t n, const wchar_t *format, ...);
int swscanf(const wchar_t *s, const wchar_t *format, ...);
int vfwprintf(FILE *stream, const wchar_t *format, va_list arg);
int vwprintf(const wchar_t *format, va_list arg);
int vswprintf(wchar_t *s, size_t n, const wchar_t *format,
     va_list arg);
```

D.16.2 Wide-character input/output functions

```
wint_t fgetwc(FILE *stream);
wchar_t *fgetws(wchar_t *s, int n, FILE *stream);
wint_t fputwc(wchar_t c, FILE *stream);
int fputws(const wchar_t *s, FILE *stream);
wint_t getwc(FILE *stream);
wint_t getwchar(void);
wint_t putwc(wchar_t c, FILE *stream);
wint_t putwchar(wchar_t c);
wint_t ungetwc(wint_t c, FILE *stream);
int fwide(FILE *stream, int mode);
```

D.16.3 Wide-string numeric conversion functions

```
double wcstod(const wchar_t *nptr, wchar_t **endptr);
long int wcstol(const wchar_t *nptr, wchar_t **endptr, int base);
unsigned long int wcstoul(const wchar_t *nptr, wchar_t **endptr,
     int base);
```

D.16.4 Wide-string functions

```
wchar_t *wcscpy(wchar_t *s1, const wchar_t *s2);
wchar_t *wcsncpy(wchar_t *s1, const wchar_t *s2, size_t n);
wchar_t *wcscat(wchar_t *s1, const wchar_t *s2);
wchar_t *wcsncat(wchar_t *s1, const wchar_t *s2, size_t n);
int wcscmp(const wchar_t *s1, const wchar_t *s2);
int wcscoll(const wchar_t *s1, const wchar_t *s2);
int wcsncmp(const wchar_t *s1, const wchar_t *s2, size_t n);
size_t wcsxfrm(wchar_t *s1, const wchar_t *s2, size_t n);
wchar_t *wcschr(const wchar_t *s, wchar_t c);
size_t wcscspn(const wchar_t *s1, const wchar_t *s2);
wchar_t *wcspbrk(const wchar_t *s1, const wchar_t *s2);
wchar_t *wcsrchr(const wchar_t *s, wchar_t c);
size_t wcsspn(const wchar_t *s1, const wchar_t *s2);
wchar_t *wcsstr(const wchar_t *s1, const wchar_t *s2);
wchar_t *wcstok(wchar_t *s1, const wchar_t *s2, wchar_t **ptr);
size_t wcslen(const wchar_t *s);
wchar_t *wmemchr(const wchar_t *s, wchar_t c, size_t n);
int wmemcmp(const wchar_t *s1, const wchar_t *s2, size_t n);
wchar_t *wmemcpy(wchar_t *s1, const wchar_t *s2, size_t n);
wchar_t *wmemmove(wchar_t *s1, const wchar_t *s2, size_t n);
wchar_t *wmemset(wchar_t *s, wchar_t c, size_t n);
```

D.16.5 Wide-string time conversion functions

```
size_t wcsftime(wchar_t *s, size_t maxsize,
     const wchar_t *format, const struct tm *timeptr);
```

D.16.6 Extended multibyte/wide-character conversion functions

```
wint_t btowc(int c);
int wctob(wint_t c);
int mbsinit(const mbstate_t *ps);
size_t mbrlen(const char *s, size_t n, mbstate_t *ps);
size_t mbrtowc(wchar_t *pwc, const char *s, size_t n,
     mbstate_t *ps);
size_t wcrtomb(char *s, wchar_t wc, mbstate_t *ps);
size_t mbsrtowcs(wchar_t *dst, const char **src, size_t len,
     mbstate_t *ps);
size_t wcsrtombs(char *dst, const wchar_t **src, size_t len,
     mbstate_t *ps);
```

Annex E
(informative)
Implementation limits

[1] The contents of a header **<limits.h>** are given below, in alphabetic order. The minimum magnitudes shown shall be replaced by implementation-defined magnitudes with the same sign. The values shall all be constant expressions suitable for use in **#if** preprocessing directives. The components are described further in 5.2.4.2.1.

```
#define CHAR_BIT                           8
#define CHAR_MAX     UCHAR_MAX or SCHAR_MAX
#define CHAR_MIN             0 or SCHAR_MIN
#define INT_MAX                      +32767
#define INT_MIN                      -32767
#define LONG_MAX                +2147483647
#define LONG_MIN                -2147483647
#define MB_LEN_MAX                         1
#define SCHAR_MAX                       +127
#define SCHAR_MIN                       -127
#define SHRT_MAX                     +32767
#define SHRT_MIN                     -32767
#define UCHAR_MAX                        255
#define UINT_MAX                       65535
#define ULONG_MAX                 4294967295
#define USHRT_MAX                      65535
```

[2] The contents of a header **<float.h>** are given below. The value of **FLT_RADIX** shall be a constant expression suitable for use in **#if** preprocessing directives. Values that need not be constant expressions shall be supplied for all other components. The components are described further in 5.2.4.2.2.

```
#define FLT_ROUNDS
```

[3] The values given in the following list shall be replaced by implementation-defined expressions that shall be equal or greater in magnitude (absolute value) to those shown, with the same sign:

```
#define DBL_DIG                              10
#define DBL_MANT_DIG
#define DBL_MAX_10_EXP                      +37
#define DBL_MAX_EXP
#define DBL_MIN_10_EXP                      -37
#define DBL_MIN_EXP
#define FLT_DIG                               6
#define FLT_MANT_DIG
#define FLT_MAX_10_EXP                      +37
#define FLT_MAX_EXP
#define FLT_MIN_10_EXP                      -37
#define FLT_MIN_EXP
#define FLT_RADIX                             2
#define LDBL_DIG                             10
#define LDBL_MANT_DIG
#define LDBL_MAX_10_EXP                     +37
#define LDBL_MAX_EXP
#define LDBL_MIN_10_EXP                     -37
#define LDBL_MIN_EXP
```

[4] The values given in the following list shall be replaced by implementation-defined expressions that shall be equal to or greater than those shown:

```
#define DBL_MAX                           1E+37
#define FLT_MAX                           1E+37
#define LDBL_MAX                          1E+37
```

[5] The values given in the following list shall be replaced by implementation-defined expressions that shall be equal to or less than those shown:

```
#define DBL_EPSILON                        1E-9
#define DBL_MIN                           1E-37
#define FLT_EPSILON                        1E-5
#define FLT_MIN                           1E-37
#define LDBL_EPSILON                       1E-9
#define LDBL_MIN                          1E-37
```

Annex F
(normative)
IEC 559 Floating-Point Arithmetic

F.1 Introduction

[1] This annex specifies C language support for the IEC 559 floating-point standard. The IEC 559 floating-point standard is specifically Binary floating-point arithmetic for microprocessor systems (IEC 559:1989), also known as IEEE Standard for Binary Floating-Point Arithmetic (ANSI/IEEE 754-1985). IEEE Standard for Radix-Independent Floating-Point Arithmetic (ANSI/IEEE 854-1987) generalizes the binary standard to remove dependencies on radix and word length. IEC 559 generally refers to the floating-point standard, as in IEC 559 operation, IEC 559 format, etc. An implementation that defines **`__STDC_IEC_559__`** conforms to the specification in this annex. Where a binding between the C language and IEC 559 is indicated, the IEC 559-specified behavior is adopted by reference, unless stated otherwise.

F.2 Types

[1] The C floating types match the IEC 559 formats as follows:

— The **`float`** type matches the IEC 559 single format.

— The **`double`** type matches the IEC 559 double format.

— The **`long double`**type**`matches`**an**`IEC`**559**`extended`** format,[203] else a non-IEC 559 extended format, else the IEC 559 **`double`** format.

Any non-IEC 559 extended format used for the **`long double`** type has more precision than IEC 559 **`double`** and at least the range of IEC 559 **`double`**.[204]

Recommended practice

[2] The **`long double`** type matches an IEC 559 extended format.

203. Extended is IEC 559's double-extended data format. Extended refers to both the common 80-bit and quadruple 128-bit IEC 559 formats.

204. A non-IEC 559 **`long double`** type must provide infinities and NaNs, as its values must include all **`double`** values.

F.2.1 Infinities, signed zeros, and NaNs

[1] This specification does not define the behavior of signaling NaNs.[205] It generally uses the term NaN to denote quiet NaNs. The NAN and INFINITY macros and the nan function in **`<math.h>`** provide designations for IEC 559 NaNs and infinities.

F.3 Operators and functions

[1] C operators and functions provide IEC 559 required and recommended facilities as listed below.

— The **`+`**, **`-`**, **`*`**, and **`/`** operators provide the IEC 559 add, subtract, multiply, and divide operations.

— The **`sqrt`** function in **`<math.h>`** provides the IEC 559 square root operation.

— The **`rem`** function in **`<math.h>`** provides the IEC 559 remainder operation. The **`remquo`** function in **`<math.h>`** provides the same operation but with additional information.

— The **`rint`** function in **`<math.h>`** provides the IEC 559 operation that rounds a floating-point number to an integral value (in the same precision). The C **`nearbyint`** function in **`<math.h>`** provides the equivalent **`nearbyinteger`** function recommended in the Appendix to IEEE standard 854.

— The conversions for floating types provide the IEC 559 conversions between floating-point precisions.

— The conversions from integral to floating types provide the IEC 559 conversions from integer to floating point.

— The conversions from floating to integral types provide IEC 559-like conversions but always round toward zero.

— The **`rinttol`** function in **`<math.h>`**provides**the**IEC 559 conversions, which honor the directed rounding mode, from floating point to the long integer format. The **`rinttol`** function can be used in conjunction with casts to provide IEC 559 conversions from floating to other integer formats.

— The translation time conversion of floating constants and the **`strtod`**, **`fprintf`**, and related library functions in **`<stdlib.h>`** and **`<stdio.h>`** provide IEC 559 binary-decimal conversions. The **`strtold`** function in **`<stdlib.h>`** provides the conv function recommended in the Appendix to IEEE standard 854.

— The relational and equality operators provide IEC 559 comparisons. IEC 559 identifies a need for additional comparison predicates to facilitate writing code that accounts for

205. Since NaNs created by IEC 559 operations are always quiet, quiet NaNs (along with infinities) are sufficient for closure of the arithmetic.

NaNs. The comparison functions (**isgreater**, **isgreaterequal**, **isless**, **islessequal**, **islessgreater**, and **isunordered**)**in <math.h>** supplement the language operators to address this need. The **islessgreater** and **isunordered** macros provide respectively a quiet version of the **< >** predicate and the unordered predicate recommended in the Appendix to IEC 559.

— The **feclearexcept**, **feraiseexcept**, and **fetestexcept**functions**in <fenv.h>** provide the facility to test and alter the IEC 559 floating-point exception flags. The **fegetexceptflag** and **fesetexceptflag** functions in **<fenv.h>** provide the facility to save and restore all five status flags at one time. These functions are used in conjunction with the type **fexcept_t** and the exception macros (**FE_INEXACT**, **FE_DIVBYZERO**, **FE_UNDERFLOW**, **FE_OVERFLOW**, **FE_INVALID**) also in **<fenv.h>**.

— The **fegetround** and **fesetround** functions in **<fenv.h>** provide the facility to select among the IEC 559 directed rounding modes represented by the rounding direction macros (**FE_TONEAREST**, **FE_UPWARD**, **FE_DOWNWARD**, **FE_TOWARDZERO**) also in **<fenv.h>**.

— The **fegetenv**, **feholdexcept**, **fesetenv**, and **feupdateenv** functions in **<fenv.h>** provide a facility to manage the floating-point environment, comprising the IEC 559 status flags and control modes.

— The **copysign** function in **<math.h>** provides the **copysign** function recommended in the Appendix to IEC 559.

— The unary minus (−) operator provides the minus (−) operation recommended in the Appendix to IEC 559.

— The **scalb** function in **<math.h>** provides the **scalb** function recommended in the Appendix to IEC 559.

— The **logb** function in **<math.h>** provides the logb function recommended in the Appendix to IEC 559, but following the newer specification in IEEE 854.

— The **nextafter** functions in **<math.h>** provides the nextafter function recommended in the Appendix to IEC 559 (but with a minor change to better handle signed zeros).

— The **isfinite** macro in **<math.h>**provides**the**finite function recommended in the Appendix to IEC 559.

— The **isnan** macro in **<math.h>** provides the **isnan** function recommended in the Appendix to IEC 559.

— The **signbit** macro and the **fpclassify** macro, used in conjunction with the number classification macros (**FP_NAN**, **FP_INFINITE**, **FP_NORMAL**, **FP_SUBNORMAL**, **FP_ZERO**), in **<math.h>** provide the facility of the class function recommended in the Appendix to IEC 559 (except that **fpclassify** does not distinguish signaling from quiet NaNs).

F.4 Floating to integral conversion

[1] If the floating value is infinite or NaN or if the integral part of the floating value exceeds the range of the integral type, then the invalid exception is raised and the resulting value is unspecified. Whether conversion of nonintegral floating values whose integral part is within the range of the integral type raises the inexact exception is unspecified.[206]

F.5 Binary-decimal conversion

[1] Conversion from the widest supported IEC 559 format to decimal with **`DECIMAL_DIG`** digits an back is the identity function.[207]

[2] Conversions involving IEC 559 formats follow all pertinent recommended practice. In particular, conversion between any supported IEC 559 format and decimal with **`DECIMAL_DIG`** or fewer significant digits is correctly rounded.

F.6 Contracted expressions

[1] A contracted expression treats infinities, NaNs, signed zeros, subnormals, and the rounding directions in a manner consistent with the basic arithmetic operations covered by IEC 559.

Recommended practice

[2] A contracted expression raises exceptions in a manner generally consistent with the basic arithmetic operations. A contracted expression delivers the same value as its uncontracted counterpart, else is correctly rounded (once).

---

206. IEEE 854, but not IEC 559 (IEEE 754), directly specifies that floating-to-integral conversions raise the *inexact* exception for nonintegral in-range values. In those cases where it matters, library functions can be used to effect such conversions with or without raising the inexact exception. See **`rint`**, **`rinttol`**, and **`nearbyint`** in **`<math.h>`**.

207. If the minimum-width IEC 559 extended format (64 bits of precision) is supported, **`DECIMAL_DIG`** must be at least **`21`**. If IEC 559 **`double`** (53 bits of precision) is the widest IEC 559 format supported, then **`DECIMAL_DIG`** must be at least **`17`**. (By contrast, **`LDBL_DIG`** and **`DBL_DIG`** are **`19`** and **`15`**, respectively, for these formats.)

F.7 Environment

[1] The floating-point environment defined in <fenv.h> includes the IEC 559 exception status flags and directed-rounding control modes. It includes also IEC 559 dynamic rounding precision and trap enablement modes, if the implementation supports them.[208]

F.7.1 Environment management

[1] IEC 559 requires that floating-point operations implicitly raise exception status flags, and that rounding control modes can be set explicitly to affect result values of floating-point operations. When the state for the **`FENV_ACCESS`**macros (defined in **`<fenv.h>`**) is on, these changes to the floating-point state are treated as side effects which respect sequence points.[209]

F.7.2 Translation

[1] During translation the IEC 559 default modes are in effect:

— The rounding direction mode is rounding to nearest.

— The rounding precision mode (if supported) is set so that results are not shortened.

— Trapping or stopping (if supported) is disabled on all exceptions.

Recommended practice

[2] The implementation provides a non-fatal diagnostic for each translation-time floating-point exception, other than inexact.[210]

F.7.3 Execution

[1] At program startup the floating-point environment is initialized as prescribed by IEC 559:

— All exception status flags are clear.

— The rounding direction mode is rounding to nearest.

— The dynamic rounding precision mode (if supported) is set so that results are not shortened.

— Trapping or stopping (if supported) is disabled on all exceptions.

---

208. This specification does not require dynamic rounding precision nor trap enablement modes.

209. If the state for the **`FENV_ACCESS`** macros is off, the implementation is free to assume the modes will be the default ones and the flags will not be tested, which allows certain optimizations see F.8.

210. As floating constants are converted to appropriate internal representations at translation time, their conversion is subject to default rounding modes and raises no execution-time exceptions (even when the state of **`FENV_ACCESS`** in on). Library functions, for example **`strtod`**, provide execution-time conversion of numeric strings.

F.7.4 Constant expressions

[1] An arithmetic constant expression of floating type, other than one in an initializer for an object that has static storage duration or in an initializer list for an object that has aggregate or union type, is evaluated (as if) during execution. As execution-time evaluation, it is affected by any operative modes and raises exceptions as required by IEC 559 (provided the state for **FENV_ACCESS** is on).[211]

Example

[2]

```
#include <fenv.h>
FENV_ACCESS_ON;
void f(void)
{
     float w[] = { 0.0/0.0 }; /* does not raise an exception */
     static float x = 0.0/0.0; /* does not raise an exception */
     float y = 0.0/0.0; /* raises an exception */
     double z = 0.0/0.0; /* raises an exception */
     /*...*/
}
```

[3] For the aggregate and static initializations, the division is done at translation time, raising no (execution-time) exceptions. On the other hand, for the two automatic scalar initializations the invalid division occurs at execution time.

F.7.5 Initialization

[1] All computation for automatic scalar initialization is done (as if) at execution time. As execution-time evaluation, it is affected by any operative modes and raises exceptions as required by IEC 559 (provided the state for **fenv_access** is on). All computation for initialization of objectst hat have static storage duration or that have aggregate or union type is done (as if) at translation time.

Example

[2]

211. Where the state for **FENV_ACCESS** is on, results of inexact expressions like **1.0/3.0** are affected by rounding modes set at execution time, and expressions such as **0.0/0.0** and **1.0/0.0** generate execution-time exceptions. The programmer can achieve the efficiency of translation-time evaluation through static initialization, such as

```
const static double one_third = 1.0/3.0;
```

```
#include <fenv.h>
FENV_ACCESS_ON;
void f(void)
{
    float u[] = { 1.1e75 }; /* does not raise exceptions */
    static float v = 1.1e75; /* does not raise exceptions */
    float w = 1.1e75; /* raises exceptions */
    double x = 1.1e75; /* may raise exceptions */
    float y = 1.1e75f; /* may raise exceptions */
    long double z = 1.1e75; /* does not raise exceptions */
    /*...*/
}
```

[3] The aggregate and static initializations of **u** and **v** raise no (execution-time) exceptions because their computation is done at translation time. The automatic initialization of **w** requires an execution-time conversion to **float** of the wider value **1.1e75**, which raises exceptions. The automatic initializations of **x** and **y** entail execution-time conversion; however, in some expression evaluation methods, the conversions is not to a narrower format, in which case no exception is raised.[212] The automatic initialization of **z** entails execution-time conversion, but not to a narrower format, so no exception is raised. Note that the conversions of the floating constants **1.1e75** and **1.1e75f** to their internal representations occur at translation time in all cases.

F.7.6 Changing the environment

[1] Operations defined in 6.3 and functions an acros defined for the standard libraries change flags and modes just as indicated by their specification (including conformance to IEC 559). They do not change flags or modes (so as to be detectable by the user) in any other cases.

[2] If the argument to the **feraiseexcept** function in **<fenv.h>** represents IEC 559 valid coincident exceptions for atomic operations-namely *overflow* and *inexact*, or *underflow* and *inexact*-then *overflow* or *underflow* is raised before *inexact*.

212. Use of **float_t** and **double_t** variables increases the likelihood of translation-time computation. For example, the automatic initialization

```
double_t x = 1.1e75;
```

could be done at translation time, regardless of the expression evaluation method.

F.8 Optimization

[1] This section identifies code transformations that might subvert IEC 559-specified behavior, and others that do not.

F.8.1 Global transformations

[1] Floating-point arithmetic operations and external function calls may entail side effects which optimization must honor, at least where the state for **FENV_ACCESS** is on. The flags and modes in the floating-point environment may be regarded as global variables; floating-point operations (+, *, etc.) implicitly read the modes and write the flags.

[2] Concern about side effects may inhibit code motion and removal of seemingly useless code. For example, in

```
#include <fenv.h>
FENV_ACCESS_ON;
void f(double x)
{
     /*...*/
     for (i = 0; i < n; i++) x + 1;
     /*...*/
}
```

x + 1 might raise exceptions, so cannot be removed. And since the loop body might not execute (maybe **0 > n**), **x + 1** cannot **be** moved out of the loop. (Of course these optimizations are valid if the implementation can rule out the nettlesome cases.)

[3] This specification does not require support for trap handlers that maintain information about the order or count of exceptions. Therefore, between function calls exceptions need not be precise: the actual order and number of occurrences of exceptions (> 1) may vary from what the source code expresses. Thus the preceding loop could be treated as

```
if (0 < n) x + 1;
```

F.8.2 Expression transformations

[1]

x / 2 <--> x * 0.5	Although similar transformations involving inexact constants generally do not yield numerically equivalent expressions, if the constants are exact then such transformations can be made on IEC 559 machines and others that round perfectly.
1 * x, x / 1 --> x	The expression **1 * x** and **x**, and **x / 1** and **x** are equivalent (on IEC 559 machines, among others).[213]

213. Strict support for signaling NaNs not required by this specification would invalidate these and other transformations that remove arithmetic operators.

x - y <--> x + (-y)	The expressions **`x - y`**, **`x + (-y)`**, and **`(-y) + x`** are equivalent (on IEC 559 machines, among others).
x - y <--> -(y - x)	The expressions **`x - y`** and **`-(y - x)`** are not equivalent because **`1 - 1`** is +**`0`** but **`-(1 - 1)`** is **`-0`** (in the default rounding direction).[214]
x - x --> 0.0	The expressions **`x - x`** and **`0.0`** are not equivalent if **`x`** is a NaN or infinite.
0 * x --> 0.0	The expressions **`0 * x`** and **`0.0`** are not equivalent if **`x`** is a NaN or infinite.
x + 0 --> x	The expressions **`x + 0`** and **`x`** are not equivalent if **`x`** is **`-0`**, because **`(-0) + (+0)`** yields **`+0`** (in the default rounding direction), not **`-0`**.
x - 0 --> x	**`(+0) - (+0)`** yields **`-0`** when rounding is downward (toward $-\infty$), but **`+0`** otherwise, and **`(-0) - (+0)`** always yields **`-0`**; so, if the state for **`FENV_ACCESS`** is off, promising default rounding, then the implementation can replace **`x - 0`** by **`x`**, even if **`x`** might be zero.
-x <--> 0 - x	The expressions **`-x`** and **`0 - x`** are not equivalent if **`x`** is **`+0`**, because **`-(+0)`** yields **`-0`**, but **`0 - (+0)`** yields **`+0`** (unless rounding is downward).

F.8.3 Relational operators

[1]

x != x --> false	The statement **`x != x`** is true if **`x`** is a NaN.
x == x --> true	The statement **`x == x`** is false if **`x`** is **`a`** NaN.
x < y --> isless(x,y)	(and similarly for **`<=`**, **`>`**, **`>=`**). Though numerically equal, these expressions are not equivalent because of side effects when **`x`** or **`y`** is a NaN and the state for **`FENV_ACCESS`** is on. This transformation, which would be desirable if extra code were required to cause the invalid exception for unordered cases, could be performed provided the state for **`FENV_ACCESS`** is off.

The sense of relational operators must be maintained. This includes handling unordered cases as expressed by the source code.

---

214. IEC 559 prescribes a signed zero to preserve mathematical identities across certain discontinuities. Examples include

`1 / (1 / (±∞))` is ±∞

`complex_conjugate(sqrt(z))` is **`sqrt(complex_conjugate(z))`**

Example

[2]

```
if (a < b)
     f();
else
     /* calls g and raises invalid */
     /* if a and b are unordered */
     g();
```

is not equivalent to

```
if (a >= b)
     g();
else
     /* calls f and raises invalid */
     /* if a and b are unordered */
     f();
```

nor to

```
if (isgreaterequal(a, b))
     g();
else
     /* calls f without raising invalid */
     /* if a and b are unordered */
     f();
```

nor, unless the state of FENV_ACCESS is off, to

```
if (isless(a, b))
     f();
else
     /* calls g without raising invalid */
     /* if a and b are unordered */
     g();
```

but is equivalent to

```
if (!(a < b))
     g();
else
     f();
```

F.8.4 Constant arithmetic

[1] The implementation must honor exceptions raised by execution-time constant arithmetic wherever the state for **FENV_ACCESS** is on. (See 7.7.4 and 7.7.5.) An operation on constants that raises no exception can be folded during translation, except, if the state for **FENV_ACCESS** is on, a further check is required to assure that changing the rounding direction to downward does not alter the sign of the result,[215] and implementations that support dynamic rounding precision modes must assure further that the result of the operation raises no exception when converted to the semantic type of the operation.

F.9 **<math.h>**

[1] This subclause contains specification of <math.h> facilities that is particularly suited for IEC 559 implementations.

[2] The Standard C macro **HUGE_VAL** and its **float** and **long double** analogs, **HUGE_VALF** and **HUGE_VALL**, expand to expressions whose values are positive infinities.

[3] Special cases for functions in **<math.h>** are covered directly or indirectly by IEC 559. 7.3 identifies the functions that IEC 559 specifies directly. The other functions in **<math.h>** treat infinities, NaNs, signed zeros, subnormals, and (provided the state for **FENV_ACCESS** is on) the exception flags in a manner consistent with the basic arithmetic operations covered by IEC 559.

[4] The *invalid* and *divide-by-zero* exceptions are raised as specified in subsequent subclauses of this annex.

[5] The *overflow* exception is raised whenever an infinity-or, because of rounding direction, a maximal-magnitude finite number-is returned in lieu of a value whose magnitude is too large.

[6] The *underflow* exception is raised whenever a result is tiny (essentially subnormal or zero) and suffers loss of accuracy.[216]

[7] Whether or when the trigonometric, hyperbolic, base-e exponential, base-e logarithmic, error, and lgamma functions raise the *inexact* exception is implementation-defined. For other functions, the *inexact* exception is raised whenever the rounded result is not identical to the mathematical result.

[8] Whether the *inexact* exception may be raised when the rounded result actually does equal the mathematical result is implementation-defined. Whether the *underflow* (and *inexact*) exception may be raised when a result is tiny but not inexact is implementation-defined.[217] Otherwise, as implied by 7.7.6, the **<math.h>** functions do not raise spurious

215. **0 - 0** yields **-0** instead of **+0** just when the rounding direction is downward.

216. IEC 559 allows different definitions of underflow. They all result in the same values, but differ on when the exception is raised.

217. It is intended that undeserved *underflow* and *inexact* exceptions are raised only if determining inexactness would be too costly.

exceptions (detectable by the user).

[9] Whether the functions honor the rounding direction mode is implementation-defined.

[10] Generally, one-parameter functions of a NaN argument return that same NaN and raise no exception.

[11] The specification in the following subclauses appends to the definitions in **`<math.h>`**.

F.9.1 Trigonometric functions

F.9.1.1 The acos function

[1]

- **`acos(1)`** returns **`+0`**.
- **`acos(x)`** returns a NaN and raises the invalid exception for **`|x| > 1`**.

F.9.1.2 The `asin` function

[1]

- **`asin(`**$\pm$**`0)`** returns $\pm$**`0`**.
- **`asin(x)`** returns a NaN and raises the invalid exception for **`|x| > 1`**.

F.9.1.3 The `atan` function

[1]

- **`atan(`**$\pm$**`0)`** returns $\pm$**`0`**.
- **`atan(`**$\pm\infty$**`)`** returns $\pm\pi$**`/2.`**

F.9.1.4 The `atan2` function

[1]

- If one argument is a NaN then **`atan2`** returns that same NaN; if both arguments are NaNs then **`atan2`** returns one of its arguments.
- **`atan2(`**$\pm$**`0, x)`** returns $\pm$**`0`**, for **`x > 0`**.
- **`atan2(`**$\pm$**`0, +0)`** returns $\pm$**`0`**.[218]
- **`atan2(`**$\pm$**`0, x)`** returns $\pm\pi$, for **`x < 0`**.
- **`atan2(`**$\pm$**`0, -0)`** returns $\pm\pi$.
- **`atan2(y,`** $\pm$**`0)`** returns π**`/2`** for **`y > 0`**.

218. **`atan2(0, 0)`** does not raise the *invalid* exception, nor does **`atan2(y, 0)`** raise the *divide-by-zero* exception.

- **atan2(y, ±0)** returns **-π/2** for **y < 0**.
- **atan2(±y, ∞)** returns ±**0**, for finite **y > 0**.
- **atan2(±∞, x)** returns ±**π/2**, for finite **x**.
- **atan2(±y, -∞)** returns ±π, for finite **y > 0**.
- **atan2(±∞, ∞)** returns ±**π/4**.
- **atan2(±∞, -∞)** returns ±**3π/4**.

F.9.1.5 The cos function

[1]

- **cos(±0)** returns **1**.
- **cos(±∞)** returns a **NaN** and raises the *invalid* exception.

F.9.1.6 The sin function

[1]

- **sin(±0)** returns ±**0**.
- **sin(±∞)** returns a **NaN** and raises the *invalid* exception.

F.9.1.7 The tan function

[1]

- **tan(±0)** returns ±**0**.
- **tan(±∞)** returns a **NaN**and**raises**the *invalid* exception.

F.9.2 Hyperbolic functions

F.9.2.1 The acosh function

[1]

- **acosh(1)** returns **+0**.
- **acosh(+∞)** returns **+**∞.
- **acosh(x)** returns a NaN and raises the invalid exception if **x < 1**.

F.9.2.2 The asinh function

[1]

- **asinh(±0)** returns ±**0**.
- **asinh(±∞)** returns ±∞.

F.9.2.3 The `atanh` function

[1]

- **`atanh(`**±**`0)`** returns ±**`0`**.
- **`atanh(`**±**`1)`** returns ±∞ and raises the *divide-by-zero* exception.
- **`atanh(x)`** returns a NaN and raises the invalid exception if **`|x| > 1`**.

F.9.2.4 The `cosh` function

[1]

- **`cosh(`**±**`0)`** returns **`1`**.
- **`cosh(`**±∞**`)`** returns **`+`**∞.

F.9.2.5 The `sinh` function

[1]

- **`sinh(`**±**`0)`** returns ±**`0`**.
- **`sinh(`**±∞**`)`** returns ±∞.

F.9.2.6 The `tanh` function

[1]

- **`tanh(`**±**`0)`** returns ±**`0`**.
- **`tanh(`**±∞**`)`** returns ±**`1`**.

F.9.3 Exponential and logarithmic functions

F.9.3.1 The `exp` function

[1]

- **`exp(`**±**`0)`** returns **`1`**.
- **`exp(+`**∞**`)`** returns **`+`**∞.
- **`exp(-`**∞**`)`** returns **`+0`**.

F.9.3.2 The `exp2` function

[1]

- **`exp2(`**±**`0)`** returns **`1`**.
- **`exp2(+`**∞**`)`** returns **`+`**∞.
- **`exp2(-`**∞**`)`** returns **`+0`**.

F.9.3.3 The `expm1` function

[1]

- **`expm1(`**±**`0)`** returns ±**`0`**.
- **`expm1(+`**∞**`)`** returns **`+`**∞.
- **`expm1(-`**∞**`)`** returns **`-1`**.

F.9.3.4 The `frexp` function

[1]

- **`frexp(`**±**`0, exp)`** returns ±**`0,`** and **`returns 0`** in **`*exp`**.
- **`frexp(`**±∞**`, exp)`** returns ±∞, and returns an unspecified value in **`*exp`**.
- **`frexp(x, exp)`** returns **`x`** if **`x`** is a NaN, and stores an unspecified value in **`*exp`**.
- **`frexp`** raises no exception.

[2] On a binary system, **`frexp`** is equivalent to the comma expression

```
( (*exp = (value == 0) ?
      0 :
      (int)(1 + logb(value))),
      scalb(value, -(*exp)) )
```

F.9.3.5 The `ldexp` function

[1] On a binary system, **`ldexp(x, exp)`** is equivalent to

```
scalb(x, exp)
```

F.9.3.6 The `log` function

[1]

- **`log(`**±**`0)`** returns **`-`**∞ and raises the *divide-by-zero* exception.
- **`log(1)`** returns **`+0`**.
- **`log(x)`** returns a NaN and raises the invalid exception if **`x < 0`**.
- **`log(+`**∞**`)`** returns **`+`**∞**`.`**

F.9.3.7 The `log10` function

[1]

- **`log10(`**±**`0)`** returns **`-`**∞ and raises the *divide-by-zero* exception.
- **`log10(1)`** returns **`+0`**.
- **`log10(x)`** returns a NaN and raises the invalid exception if **`x < 0`**.
- **`log10(+`**∞**`)`** returns **`+`**∞.

F.9.3.8 The `log1p` function

[1]

- **`log1p(`**±**`0)`** returns ±0.
- **`log1p(-1)`** returns **`-`**∞ and raises the *divide-by-zero* exception.
- **`log1p(x)`** returns a NaN and raises the invalid exception if **`x < -1`**.
- **`log1p(+`**∞**`)`** returns **`+`**∞.

F.9.3.9 The `log2` function

[1]

- **`log2(`**±**`0)`** returns **`-`**∞ and raises the *divide-by-zero* exception.
- **`log2(x)`** returns a NaN and raises the *invalid* exception if **`x < 0`**.
- **`log2(+`**∞**`)`** returns **`+`**∞.

F.9.3.10 The `logb` function

[1]

- **`logb(`**±∞**`)`** returns **`+`**∞.
- **`logb(`**±**`0)`** returns **`-`**∞ and raises the *divide-by-zero* exception.

F.9.3.11 The `modf` functions

[1]

- **`modf(value, iptr)`** returns a result with the same sign as the argument value.
- **`modf(`**±∞**`, iptr)`**returns ±**`0`** and stores ±∞ through **`iptr`**.
- **`modf`** of a NaN argument returns that same NaN and also stores it through **`iptr`**.

[2] **`modf`** behaves as though implemented by

```
#include <math.h>
#include <fenv.h>
FENV_ACCESS_ON;
double modf(double value, double *iptr)
{
     int save_round = fegetround();
     fesetround(FE_TOWARDZERO);
     *iptr = nearbyint(value);
     fesetround(save_round);
     return copysign(
     (fabs(value) == INFINITY) ?
          0.0 :
          value - (*iptr), value);
}
```

F.9.3.12 The `scalb` function

[1]

- **`scalb(x, n)`** returns **`x`** if **`x`** is infinite, zero, or a NaN.
- **`scalb(x, 0)`** returns **`x`**.

F.9.4 Power and absolute value functions

F.9.4.1 The `fabs` function

[1]

- **`fabs(`**±**`0)`** returns **`+0`**.
- **`fabs(`**±∞**`)`** returns **`+`**∞.

F.9.4.2 The `hypot` function

[1]

- **`hypot(x, y)`**, **`hypot(y, x)`**, and **`hypot(x, -y)`** are equivalent.
- **`hypot(x, y)`** returns **`+`**∞ if **`x`** is infinite.
- If both arguments are NaNs then **`hypot`** returns one of its arguments; otherwise, if **`x`** is a NaN and **`y`** in not infinite then **`hypot`** returns that same NaN.
- **`hypot(x, `**±**`0)`** is equivalent to **`fabs(x)`**.[219]

219. **`hypot(`**∞**`, NAN)`** returns **`+`**∞, under the justification that **`hypot(`**∞**`, y)`** is **`+`**∞ for any numeric value **`y`**.

F.9.4.3 The `pow` function

[1]

- **`pow(x, ±0)`** returns **`1`** for any **`x`**.
- **`pow(x, +∞)`** returns **`+∞`**for **`|x| > 1`**.
- **`pow(x, +∞)`** returns **`+0`** for **`|x| < 1`**.
- **`pow(x, -∞)`** returns **`+0`** for **`|x| > 1`**.
- **`pow(x, -∞)`** returns **`+∞`** for **`|x| < 1`**.
- **`pow(+∞, y)`** returns **`+∞`** for **`y > 0`**.
- **`pow(+∞, y)`** returns **`+0`** for **`y < 0`**.
- **`pow(-∞, y)`** returns **`-∞`** for **`y`** an odd integer **`> 0`**.
- **`pow(-∞, y)`** returns **`+∞`** for **`y > 0`** and not an odd integer.
- **`pow(-∞, y)`** returns **`-0`** for **`y`** an odd integer **`< 0`**.
- **`pow(-∞, y)`** returns **`+0`** for **`y < 0`** and not an odd integer.
- **`pow(x, y)`** returns one of its NaN arguments if **`y`** is a NaN, or if **`x`** is a NaN and **`y`** is nonzero.
- **`pow(±1, ±∞)`** returns a NaN and raises the *invalid* exception.
- **`pow(x, y)`** returns a NaN and raises the *invalid* exception for finite **`x < 0`** and finite nonintegral **`y`**.
- **`pow(±0, y)`** returns ±∞ and raises the *divide-by-zero* exception for **`y`** an odd integer **`< 0`**.
- **`pow(±0, y)`** returns **`+∞`** and raises the *divide-by-zero* exception for **`y < 0`** and not an odd integer.
- **`pow(±0, y)`** returns ±**`0`** for **`y`** an odd integer **`> 0`**.
- **`pow(±0, y)`** returns **`+0`** for **`y > 0`** and not an odd integer.

F.9.4.4 The `sqrt` function

[1] **`sqrt`** is fully specified as a basic arithmetic operation in IEC 559.

F.9.5 Error and gamma functions

F.9.5.1 The `erf` function

[1]

- **`erf(`**±**`0)`** returns ±**`0`**.
- **`erf(`**±∞**`)`** returns ±**`1`**.

F.9.5.2 The `erfc` function

[1]

- **`erfc(+`**∞**`)`** returns **`+0`**.
- **`erfc(-`**∞**`)`** returns **`2`**.

F.9.5.3 The `gamma` function

[1]

- **`gamma(+`**∞**`)`** returns **`+`**∞.
- **`gamma(x)`** returns a NaN and raises the *invalid* exception if **`x`** is a negative integer or zero.
- **`gamma(-`**∞**`)`** returns a NaN and raises the *invalid* exception.

F.9.5.4 The `lgamma` function

[1]

- **`lgamma(+`**∞**`)`** returns **`+`**∞.
- **`lgamma(x)`** returns **`+`**∞ and raises the *divide-by-zero* exception if **`x`** is a negative integer or zero.
- **`lgamma(-`**∞**`)`** returns a NaN and raises the *invalid* exception.

F.9.6 Nearest integer functions

F.9.6.1 The `ceil` function

[1]

- ceil(x) returns x if x is ±∞ or ±0.

The double version of ceil behaves as though implemented by

```
#include <math.h>
#include <fenv.h>
FENV_ACCESS_ON;
double ceil(double x)
{
     double result;
     int save_round = fegetround();
     fesetround(FE_UPWARD);
     result = rint(x); /* or nearbyint instead of rint */
     fesetround(save_round);
     return result;
}
```

F.9.6.2 The `floor` function

[1]

- **`floor(x)`** returns **`x`** if **`x`** is $\pm\infty$ or $\pm$**`0`**.

See the sample implementation for **`ceil`** in 7.9.6.1.

F.9.6.3 The `nearbyint` function

[1] The **`nearbyint`** function differs from the **`rint`** function only in that the **`nearbyint`** function does not raise the *inexact* flag.

F.9.6.4 The `rint` function

[1] The **`rint`** function uses IEC 559 rounding according to the current rounding direction. It raises the *inexact* exception if its argument differs in value from its result.

- **`rint(`**$\pm$**`0)`** returns $\pm$**`0`** (for all rounding directions).
- **`rint(`**$\pm\infty$**`)`** returns $\pm\infty$ (for all rounding directions).

F.9.6.5 The `rinttol` function

[1] The **`rinttol`** function provides floating-to-integer conversion as prescribed by IEC 559. It rounds according to the current rounding direction. If the rounded value is outside the range of **`long int`**, the numeric result is unspecified and the *invalid* exception is raised. When it raises no other exception and its argument differs from its result, **`rinttol`** raises the *inexact* exception.

F.9.6.6 The `round` function

[1] The **`double`** version of **`round`** behaves as though implemented by

```
#include <math.h>
#include <fenv.h>
FENV_ACCESS_ON;
double round(double x)
{
     double result;
     fenv_t save_env;
     feholdexcept(&save_env);
     result = rint(x);
     if (fetestexcept(FE_INEXACT))
     {
          fesetround(FE_TOWARDZERO);
          result = rint(copysign(0.5 + fabs(x), x));
     }
     feupdateenv(&save_env);
     return result;
}
```

The **round** function may but is not required to raise the *inexact* exception for nonintegral numeric arguments, as this implementation does.

F.9.6.7 The roundtol function

[1] The **roundtol** function differs from **rinttol** with the default rounding direction just in that **roundtol** (1) rounds halfway cases away from zero and (2) may but need not raise the *inexact* exception for nonintegral arguments that round to within the range of **long int**.

F.9.6.8 The trunc function

[1] The **trunc** function uses IEC 559 rounding toward zero (regardless of the current rounding direction).

F.9.7 Remainder functions

F.9.7.1 The fmod function

[1]

- If one argument is a NaN then **fmod** returns that same NaN; if both arguments are NaNs then **fmod** returns one of its arguments.
- **fmod(±0, y)** returns **±0** if **y** is not zero.
- **fmod(x, y)** returns a NaN and raises the *invalid* exception if **x** is infinite or **y** is zero.
- **fmod(x, ±∞)** returns **x** if **x** is not infinite.

The double version of fmod behaves as though implemented by

```
#include <math.h>
#include <fenv.h>
FENV_ACCESS_ON;
double fmod(double x, double y)
{
     double result;
     result = remainder(fabs(x), (y = fabs(y)));
     if (signbit(result)) result += y;
     return copysign(result, x);
}
```

F.9.7.2 The `remainder` function

[1] The **`remainder`** function is fully specified as a basic arithmetic operation in IEC 559.

F.9.7.3 The `remquo` function

[1] The **`remquo`** function follows the specification for **`remainder`**. It has no further specification special to IEC 559 implementations.

F.9.8 Manipulation functions

F.9.8.1 The `copysign` function

[1] **`copysign`** is specified in the Appendix to IEC 559.

F.9.8.2 The `nan` function

[1] All IEC 559 implementations support quiet NaNs, in all floating formats.

F.9.8.3 The `nextafter` function

[1]

- If one argument is a NaN then **`nextafter`** returns that same NaN; if both arguments are NaNs then **`nextafter`** returns one of its arguments.
- **`nextafter(x, y)`** raises the *overflow* and *inexact* exceptions if **`x`** is finite and the function value is infinite.
- **`nextafter(x, y)`** raises the *underflow* and *inexact* exceptions if the function value is subnormal or zero and **`x != y`**.

F.9.9 Maximum, minimum, and positive difference functions

F.9.9.1 The fdim function

[1]

- If one argument is a NaN then **fdim** returns that same NaN; if both arguments are NaNs then **fdim** returns one of its arguments.

F.9.9.2 The fmax function

[1]

- If just one argument is a NaN then fmax returns the other argument; if both arguments are NaNs then fmax returns one of its arguments.

The **fmax** function might be implemented as[220]

```
{ return (isgreaterequal(x, y) ||
     isnan(y)) ? x : y; }
```

F.9.9.3 The fmin function

[1] **fmin** is analogous to **fmax**. See 7.9.9.2.

220. Ideally, **fmax** would be sensitive to the sign of zero, for example **fmax(-0.0, +0.0)** would return **+0**; however, implementation in software might be impractical.

Annex G
(normative)
IEC 559-Compatible Complex Arithmetic

G.1 Introduction

[1] This annex supplements Annex H to specify complex arithmetic for compatibility with IEC 559 real floating-point arithmetic. An implementation supports this specification if and only if it defines the macro **`__STDC_IEC_559_COMPLEX__`**; the macro expands to the decimal constant **`1`**.

G.2 Keywords

[1] The syntax in subclause 6.1.1 is extended to include the keyword

```
imaginary
```

The token imaginary is a keyword in translation units where the header **`<complex.h>`** is included, but not otherwise. If the token is used prior to the first inclusion of the header, the behavior is undefined.

G.3 Types

[1] There are three imaginary types, designated as **`float imaginary`**, **`double imaginary`**, and **`long double imaginary`**. The imaginary types (along with the real floating and complex types) are floating types.

[2] For imaginary types, the corresponding real type is given by deleting the keyword **`imaginary`** from the type name.

[3] Each imaginary type has the same representation and alignment requirements as the corresponding real type. The value of an object of imaginary type is the value of the real representation times the imaginary unit.

[4] The imaginary type-domain comprises the imaginary types.

G.4 Conversions

G.4.1 Imaginary types

[1] Conversions among imaginary types follow rules analogous to those for real floating types.

G.4.2 Real and imaginary

[1] When a value of imaginary type is converted to a real type, the result is a positive zero.

[2] When a value of real type is converted to an imaginary type, the result is a positive imaginary zero.

G.4.3 Imaginary and complex

[1] When a value of imaginary type is converted to a complex type, the real part of the complex result value is a positive zero and the imaginary part of the complex result value is determined by the conversion rules for the corresponding real types.

[2] When a value of complex type is converted to an imaginary type, the real part of the complex value is discarded and the value of the imaginary part is converted according to the conversion rules for the corresponding real types.

G.5 Binary operators

[1] The following subclauses supplement 6.3 in order to specify the type of the result for an operation with an imaginary operand.

[2] For most operand types, the value of the result of a binary operator with an imaginary or complex operand is completely determined, with reference to real arithmetic, by the usual mathematical formula. For some operand types, the usual mathematical formula is problematic because of its treatment of infinities and because of undue overflow or underflow (7.6.1); in these cases the result satisfies certain properties (specified in G.5.1), but is not completely determined.

G.5.1 Multiplicative operators

Semantics

[1] If one operand has real type and the other operand has imaginary type, then the result has imaginary type. If both operands have imaginary type, then the result has complex type. (If either operand has complex type, then the result has complex type.)

[2] If the operands are not both complex, then the result of the `*` operator is defined by the usual mathematical formula: [**Editor: The following tables need to be fixed.**]

```
*         real x    imaginary y*I  complex x + y*I

real u         x*u  (y*u)*I        (x*u) + (y*u)*I

imaginary v*I  (x*v)*I   -y*v + 0*I     (-y*v) + (x*v)*I

complex u + v*I     (x*u) + (x*v)*I (-y*v) + (y*u)*I
```

[3] If the second operand is not complex, then the result of the `/` operator is defined by the usual mathematical formula: [**Editor: The following tables need to be fixed.**]

`/`	**`x`**	**`y*I`**	**`x + y*I`**
`u`	**`x/u`**	**`(y/u)*I`**	**`(x/u) + (y/u)*I`**
`v*I`	**`(-x/v)*I`**	**`y/v + 0*I`**	**`(y/v) + (-x/v)*I`**

[4] A complex or imaginary value with at least one infinite part is regarded as an infinity (even if its other part is a NaN). A complex or imaginary value is a finite number if each of its parts is a finite number (neither infinite nor NaN). A complex or imaginary value is a zero if each of its parts is a zero. The **`*`** and **`/`** operators satisfy the following infinity properties for all real, imaginary, and complex operands:[221]

— if one operand is an infinity and the other operand is a nonzero finite number or an infinity, then the result of the **`*`** operator is an infinity;

— if the first operand is an infinity and the second operand is a finite number, then the result of the **`/`** operator is an infinity;

— if the first operand is a finite number and the second operand is an infinity, then the result of the **`/`** operator is a zero;

— if the first operand is a nonzero finite number or an infinity and the second operand is a zero, then the result of the **`/`** operator is an infinity.

[5]

Examples

1. Multiplication of **`double complex`** operands could be implemented as follows. Note that the imaginary unit **`I`** has imaginary type (see G.6).

221. These properties are already implied for those cases covered in the tables, but are required for all cases (at least where the state for **`CX_LIMITED_RANGE`** is off).

```
#include <math.h>
#include <complex.h>
#define isinf(x) (fabs(x)==INFINITY)

/* To "box" infinities ... */
static double complex box(double complex z)
{
     return copysign(isinf(real(z)) ? 1.0 : 0.0, real(z)) +
     I * copysign(isinf(imag(z)) ? 1.0 : 0.0, imag(z));
}

/* Multiply z * w ... */
double complex _Cmultd(double complex z, double complex w)
{
     double a, b, c, d, x, y;

     a = creal(z); b = cimag(z); c = creal(w); d = cimag(w);
     x = a * c - b * d;
     y = a * d + b * c;
     if (isnan(x) && isnan(y))
     {
          int recalc = 0;

          if (isinf(a) || isinf(b))  /* if z is infinite */
          {
               double complex zz;

               zz = box(z);
               a = creal(zz);
               b = cimag(zz);
               recalc = 1;
          }
          if (isinf(c) || isinf(d))  /* if w is infinite */
          {
               double complex ww;

               ww = box(w);
               c = creal(ww);
               d = cimag(ww);
               recalc = 1;
          }
          if (recalc)
          {
               x = INFINITY * (a * c - b * d);
               y = INFINITY * (a * d + b * c);
```

```
        }
    }
    return x + I * y;
}
```

[6] In ordinary (finite) cases, the cost to satisfy the infinity property for the `*` operator is only one `isnan` test. This implementation opts for performance over guarding against undue overflow and underflow.

2. Division of two `double complex` operands could be implemented as follows.

```
#include <math.h>
#include <complex.h>
/* box and isinf are as in example 1 above */

/* Divide z / w ... */
double complex _Cdivd(double complex z, double complex w)
{
    double a, b, c, d, logbw, denom, x, y;
    long llogbw = 0;

    a = creal(z); b = cimag(z); c = creal(w); d = cimag(w);
    logbw = logb(fmax(fabs(c), fabs(d)));
    if (isfinite(logbw))
    {
        llogbw = (long)logbw;
        c = scalb(c, -llogbw);
        d = scalb(d, -llogbw);
    }
    denom = c * c + d * d;
    x = scalb((a * c + b * d) / denom, -llogbw);
    y = scalb((b * c - a * d) / denom, -llogbw);
    if (isnan(x) && isnan(y))
    {
        double fact = 1;
        int recalc = 0;

        if (isinf(a) || isinf(b))  /* if z is infinite */
        {
            double complex zz;

            zz = box(z);
            fact = INFINITY;
            a = creal(zz);
            b = cimag(zz);
            recalc = 1;
        }
```

```
            if (logbw == INFINITY)  /* if w is infinite */
            {
                 double complex ww;

                 ww = box(w);
                 fact /= INFINITY;
                 c = creal(ww);
                 d = cimag(ww);
                 denom = c * c + d * d;
                 recalc = 1;
            }
            if (recalc)
            {
                 x = fact * scalb((a * c + b * d) / denom,
                      -llogbw);
                 y = fact * scalb((b * c - a * d) / denom,
                      -llogbw);
            }
       }
       return x + I * y;
  }
```

[7] Scaling the denominator alleviates the main overflow and underflow problem, which is more serious than for multiplication. In the spirit of the multiplication example above, this code does not defend against overflow and underflow in the calculation of the numerator. Scaling with the **scalb** function, instead of with division, provides better roundoff characteristics.

G.5.2 Additive operators

Semantics

[1] If one operand has real type and the other operand has imaginary type, then the result has complex type. If both operands have imaginary type, then the result has imaginary type. (If either operand has complex type, then the result has complex type.)

[2] In all cases the result of a **+** or **-** operator is defined by the usual mathematical formula:

±	**x**	**y*I**	**x + y*I**
u	**x ± u**	**±u + y*I**	**(x±u) + y*I**
v*I	**x ± v*I**	**(y±v)*I**	**x + (y±v)*I**
u + v*I	**(x±u) ± v*I**	**±u + (y±v)*I**	**(x±u) + (y±v)*I**

[3] The macro

```
_Imaginary_I
```

has an imaginary type.

[4] This subclause contains specification for the **<complex.h>** functions that is particularly suited to IEC 559 implementations.

[5] The functions are continuous onto both sides of their branch cuts, taking into account the sign of zero. For example, **csqrt(-2 ± 0*I) == ±sqrt(2)*I**.

[6] Since complex and imaginary values are composed of real values, each function may be regarded as computing real values from real values. Except as noted, the functions treat real infinities, NaNs, signed zeros, subnormals, and the exception flags in a manner consistent with the specification for real functions in G.9.

[7] The functions **conj**, **cimag**, **cproj**, and **creal** are fully specified for all implementations, including IEC 559 ones, in 7.7.2. These functions raise no exceptions.

[8] Each of the functions **cabs** and **carg** is specified by a formula in terms of a real function (whose special cases are covered in annex X):

```
cabs(x + i*y) = hypot(x, y)
carg(x + i*y) = atan2(y, x)
```

[9] Each of the functions **casin**, **catan**, **ccos**, **csin**, **ctan**, and **cpow** is specified implicitly by a formula in terms of other complex functions (whose special cases are specified below):

```
casin(z)  = -i*casinh(i*z)
catan(z)  = -i*catanh(i*z)
ccos(z)  = ccosh(i*z)
csin(z)  = -i*csinh(i*z)
ctan(z)  = -i*ctanh(i*z)
cpow(z, c)  = cexp(c * clog(z))
```

[10] For the other functions, the following subclauses specify behavior for special cases, including treatment of the *invalid* and *divide-by-zero* exceptions. For a function **f** satisfying **f(conj(z)) = conj(f(z))**, the specification for the upper half-plane implies the specification for thel ower half-plane; if also the function **f** is either even, **f(-z) = f(z)**, or odd, **f(-z) = -f(z)**, then the specification for the first quadrant implies the specification for the other three quadrants.

G.5.3 The `cacos` function

[1]

- **`cacos(conj(z)) = conj(cacos(z))`**.
- **`cacos(±0+i0)`** returns **π/2-i0**.
- **`cacos(-∞+i∞)`** returns **3π/4-i∞**.
- **`cacos(+∞+i∞)`** returns **π/4-i∞**.
- **`cacos(x+i∞)`** returns **π/2-i∞**, for finite **`x`**.
- **`cacos(-∞+iy)`** returns **π-i∞**, for positive-signed finite **`y`**.
- **`cacos(+∞+iy)`** returns **+0-i∞**, for positive-signed finite **`y`**.
- **`cacos(±∞+iNaN)`** returns **NaN±i∞** (where the sign of the imaginary part of the result is unspecified).
- **`cacos(±0+iNaN)`** returns **π/2+iNaN**.
- **`cacos(NaN+i∞)`** returns NaN-i∞.
- **`cacos(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for nonzero finite **`x`**.
- **`cacos(NaN+iy)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`y`**.
- **`cacos(NaN+iNaN)`** returns **`NaN+iNaN`**.

G.5.4 The `cacosh` function

[1]

- **`cacosh(conj(z)) = conj(cacosh(z))`**.
- **`cacosh(±0+i0)`** returns **+0+iπ/2**.
- **`cacosh(-∞+i∞)`** returns **+∞+i3π/4**.
- **`cacosh(+∞+i∞)`** returns **+∞+iπ/4**.
- **`cacosh(x+i∞)`** returns **+∞+iπ/2**, for finite **`x`**.
- **`cacosh(-∞+iy)`** returns **+∞+iπ**, for positive-signed finite **`y`**.
- **`cacosh(+∞+iy)`** returns **+∞+i0**, for positive-signed finite **`y.`**
- **`cacosh(NaN+i∞)`** returns **+∞+iNaN**.
- **`cacosh(±∞+iNaN)`** returns **+∞+iNaN**.
- **`cacosh(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`x`**.

- **`cacosh(NaN+iy)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`y`**.
- **`cacosh(NaN+iNaN)`** returns **`NaN+iNaN`**.

G.5.5 The `casinh` function

- **`casinh(conj(z))`=`conj(casinh(z))"`** and **`casinh`** is odd.
- **`casinh(+0+i0)`** returns **`0+i0`**.
- **casinh(∞+i∞)** returns **+∞+iπ/4**.
- **casinh(x+i∞)** returns **+∞+iπ/2** for positive-signed finite **`x`**.
- **casinh(+∞+iy)** returns **+∞+i0** for positive-signed finite **`y`**.
- **casinh(NaN+i∞)** returns ±∞**+iNaN** (where the sign of the real part of the result is unspecified).
- **casinh(+∞+iNaN)** returns **+∞+iNaN**.
- **`casinh(NaN+i0)`** returns **`NaN+i0`**.
- **`casinh(NaN+iy)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite nonzero **`y`**.
- **`casinh(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`x`**.
- **`casinh(NaN+iNaN)`** returns **`NaN+iNaN`**.

G.5.6 The `catanh` function

[1]

- **`catanh(conj(z)) = conj(catanh(z))`**and **`catanh`** is odd.
- **`catanh(+0+i0)`** returns **`+0+i0`**.
- **catanh(+∞+i∞)** returns **+0+iπ/2**.
- **catanh(+∞+iy)** returns **+0+iπ/2**, for finite positive-signed **`y`**.
- **catanh(x+i∞)** returns **+0+iπ/2**, for finite positive-signed **`x`**.
- **`catanh(+0+iNaN)`** returns **`+0+iNaN`**.
- **catanh(NaN+i∞)** returns ±**0+iπ/2** (where the sign of the real part of the result is unspecified).
- **catanh(+∞+iNaN)** returns **`+0+iNaN`**.
- **`catanh(NaN+iy)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`y`**.
- **`catanh(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception for nonzero finite **`x`**.

- **`catanh(NaN+iNaN)`** returns **`NaN+iNaN`**.

G.5.7 The `ccosh` function

[1]

- **`ccosh(conj(z)) = conj(ccosh(z))`** and **`ccosh`** is even.
- **`ccosh(+0+i0)`** returns **`1+i0`**.
- **`ccosh(+0+i∞)`** returns **`NaN±i0`** (where the sign of the imaginary part of the result is unspecified) and raises the *invalid* exception.
- **`ccosh(+∞+i0)`** returns **`+∞+i0`**.
- **`ccosh(+∞+i∞)`** returns **`+∞+iNaN`** and raises the *invalid* exception.
- **`ccosh(x+i∞)`** returns **`NaN+iNaN`** and raises the *invalid* exception, for finite nonzero **`x`**.
- **`ccosh(+∞+iy)`** returns **`(+∞)*cis(y)`**, for finite nonzero **`y`**.[222]
- **`ccosh(+0+iNaN)`** returns **`NaN±i0`** (where the sign of the imaginary part of the result is unspecified).
- **`ccosh(+∞+iNaN)`** returns **`+∞+iNaN`**.
- **`ccosh(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite nonzero **`x`**.
- **`ccosh(NaN+i0)`** returns **`NaN±i0`** (where the sign of the imaginary part of the result is unspecified).
- **`ccosh(NaN+iy)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for all nonzero numbers **`y`**.
- **`ccosh(NaN+iNaN)`** returns **`NaN+iNaN`**.

G.5.8 The `csinh` function

[1]

- **`csinh(conj(z)) = conj(csinh(z))`** and **`csinh`** is odd.
- **`csinh(+0+i0)`** returns **`+0+i0`**.
- **`csinh(+0+i∞)`** returns **`±0+iNaN`** (where the sign of the real part of the result is unspecified) and raises the *invalid* exception.
- **`csinh(+∞+i0)`** returns **`+∞+i0`**.

222. **`cis(y)`** is defined by **`cos(y) + i*sin(y)`**.

- **`csinh(+∞+i∞)`** returns ±∞**`+iNaN`** (where the sign of the real part of the result is unspecified) and raises the *invalid* exception.
- **`csinh(+∞+iy)`** returns (+∞)*cis(y), for positive finite **`y`**.
- **`csinh(x+i∞)`** returns **`NaN+iNaN`** and raises the invalid exception, for positive finite x.
- **`csinh(+0+iNaN)`** returns ±0+iNaN (where the sign of the real part of the result is unspecified).
- **`csinh(+∞+iNaN)`** returns ±∞+iNaN (where the sign of the real part of the result is unspecified).
- **`csinh(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite nonzero **`x`**.
- **`csinh(NaN+i0)`** returns **`NaN+i0`**.
- **`csinh(NaN+iy)`** returns **`NaN+iNaN`** and optionally raisesthe *invalid* exception, for all nonzero numbers **`y`**.
- **`csinh(NaN+iNaN)`** returns **`NaN+iNaN`**.

G.5.9 The `ctanh` function

[1]

- **`ctanh(conj(z)) = conj(ctanh(z))`**and **`ctanh`** is odd.
- **`ctanh(+0+i0)`** returns **`+0+i0`**.
- **`ctanh(+∞+iy)`** returns **`1+i0`**, for all positive-signed numbers **`y`**.
- **`ctanh(x+i∞)`** returns **`NaN+iNaN`** and raises the *invalid* exception, for finite **`x`**.
- **`ctanh(+∞+iNaN)`** returns **`1`**±**`i0`** (where the sign of the imaginary part of the result is unspecified).
- **`ctanh(NaN+i0)`** returns **`NaN+i0`**.
- **`ctanh(NaN+iy)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for all nonzero numbers **`y`**.
- **`ctanh(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`x`**.
- **`ctanh(NaN+iNaN)`** returns **`NaN+iNaN`**.

G.5.10 The `cexp` function

[1]

- **`cexp(conj(z)) = conj(cexp(z))`**.
- **`cexp(`$\pm$`0+i0)`** returns **`1+i0`**.
- **`cexp(+`∞`+i0)`** returns **`+`∞`+i0`**.
- **`cexp(-`∞`+i`∞`)`** returns **`+0+i0`**.
- **`cexp(+`∞`+i`∞`)`** returns **`+`∞`+iNaN`** and raises the *invalid* exception.
- **`cexp(x+i`∞`)`** returns **`NaN+iNaN`** and raises the *invalid* exception, for finite **`x`**.
- **`cexp(-`∞`+iy)`** returns **`+0*cis(y)`**, for finite **`y`**.
- **`cexp(+`∞`+iy)`** returns **`+`∞`*cis(y)`**, for finite nonzero **`y`**.
- **`cexp(-`∞`+iNaN)`** returns **`+0`$\pm$`i0`** (where the sign of the imaginary part of the result is unspecified).
- **`cexp(+`∞`+iNaN)`** returns **`+`∞`+iNaN`**.
- **`cexp(NaN+iy)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for all numbers **`y`**.
- **`cexp(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`x`**.
- **`cexp(NaN+iNaN)`** returns **`NaN+iNaN`**.

G.5.11 The `clog` function

[1]

- **`clog(conj(z)) = conj(clog(z))`**.
- **`clog(-0+i0)`** returns **`-`∞`+i`π** and raises the *divide-by-zero* exception.
- **`clog(+0+i0)`** returns **`-`∞`+i0`** and raises the *divide-by-zero* exception.
- **`clog(-`∞`+i`∞`)`** returns **`+`∞`+i3`π`/4`**.
- **`clog(+`∞`+i`∞`)`** returns **`+`∞`+i`π`/4`**.
- **`clog(x+i`∞`)`** returns **`+`∞`+i`π`/2`**, for finite **`x`**.
- **`clog(-`∞`+iy)`** returns **`+`∞`+i`π**, for finite positive-signed **`y`**.
- **`clog(+`∞`+iy)`** returns **`+`∞`+i0`**, for finite positive-signed **`y`**.
- **`clog(`$\pm\infty$`+iNaN)`** returns **`+`∞`+iNaN`**.
- **`clog(NaN+i`∞`)`** returns **`+`∞`+iNaN`**.
- **`clog(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`x`**.

- **`clog(NaN+iy)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`y`**.
- **`clog`**(NaN+iNaN) returns **`NaN+iNaN`**.

G.5.12 The `csqrt` function

[1]

- **`csqrt(conj(z)) = conj(csqrt(z))`**.
- **`csqrt(`**±**`0+i0)`** returns **`+0+i0`**.
- **`csqrt(-`**∞**`+iy)`** returns **`+0+i`**∞, for finite positive-signed **`y`**.
- **`csqrt(+`**∞**`+iy)`** returns **`+`**∞**`+i0`**, for finite positive-signed **`y`**.
- **`csqrt(x+i`**∞**`)`** returns **`+`**∞**`+i`**∞, for all **`x`** (including NaN).
- **`csqrt(-`**∞**`+iNaN)`** returns **`NaN`**±**`i`**∞ (where the sign of the imaginary part of the result is unspecified).
- **`csqrt(+`**∞**`+iNaN)`** returns **`+`**∞**`+iNaN`**.
- **`csqrt(x+iNaN)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`x`**.
- **`csqrt(NaN+iy)`** returns **`NaN+iNaN`** and optionally raises the *invalid* exception, for finite **`y`**.
- **`csqrt(NaN+iNaN)`** returns **`NaN+iNaN`**.

Annex H
(informative)
Common warnings

[1] An implementation may generate warnings in many situations, none of which is specified as part of this International Standard. The following are a few of the more common situations.

[2]

— A block with initialization of an object that has automatic storage duration is jumped into (6.1.2.4).

— An integer character constant includes more than one character or a wide character constant includes more than one multibyte character (6.1.3.4).

— The characters **`/*`** are found in a comment (6.1.7).

— An implicit narrowing conversion is encountered, such as the assignment of a **`long int`** or a **`double`** to an **`int`**, or a pointer to **`void`** to a pointer to any type other than a character type (6.2).

— An ‘‘unordered’’ binary operator (not comma, **`&&`** or **`||`**) contains a side-effect to an lvalue in one operand, and a side-effect to, or an access to the value of, the identical lvalue in the other operand (6.3).

— A function is called but no prototype has been supplied (6.3.2.2).

— The arguments in a function call do not agree in number and type with those of the parameters in a function definition that is not a prototype (6.3.2.2).

— An object is defined but not used (6.5).

— A value is given to an object of an enumeration type other than by assignment of an enumeration constant that is a member of that type, or an enumeration variable that has the same type, or the value of a function that returns the same enumeration type (6.5.2.2).

— An aggregate has a partly bracketed initialization (6.5.7).

— A statement cannot be reached (6.6).

— A statement with no apparent effect is encountered (6.6).

— A constant expression is used as the controlling expression of a selection statement (6.6.4).

— A function has **`return`** statements with and without expressions (6.6.6.4).

— An incorrectly formed preprocessing group is encountered while skipping a preprocessing group (6.8.1).

— An unrecognized **#pragma** directive is encountered (6.8.6).

Annex I
(informative)
Portability issues

[1] This annex collects some information about portability that appears in this International Standard.

I.1 Unspecified behavior

[1] The following are unspecified:

— The manner and timing of static initialization (5.1.2).

— The behavior if a printable character is written when the active position is at the final position of a line (5.2.2).

— The behavior if a backspace character is written when the active position is at the initial position of a line (5.2.2).

— The behavior if a horizontal tab character is written when the active position is at or past the last defined horizontal tabulation position (5.2.2).

— The behavior if a vertical tab character is written when the active position is at or past the last defined vertical tabulation position (5.2.2).

— The representations of floating types (6.1.2.5).

— The order in which expressions are evaluated — in any order conforming to the precedence rules, even in the presence of parentheses (6.3).

— The order in which side effects take place (6.3).

— The order in which the function designator and the arguments in a function call are evaluated (6.3.2.2).

— The alignment of the addressable storage unit allocated to hold a bit-field (6.5.2.1).

— The layout of storage for parameters (6.7.1).

— The order in which **#** and **##** operations are evaluated during macro substitution (6.8.3.3).

— Whether **errno** is a macro or an external identifier (7.1.4).

— Whether **setjmp** is a macro or an external identifier (7.8.1.1).

— Whether **va_end** is a macro or an external identifier (7.10.1.3).

— The value of the file position indicator after a successful call to the **ungetc** function for a text stream, until all pushed-back characters are read or discarded (7.11.7.11).

— The details of the value stored by the **fgetpos** function on success (7.11.9.1).

— The details of the value returned by the **ftell** function for a text stream on success (7.11.9.4).

— The order and contiguity of storage allocated by the **calloc**, **malloc**, and **realloc** functions (7.12.3).

— Which of two elements that compare as equal is returned by the **bsearch** function (7.12.5.1).

— The order in an array sorted by the **qsort** function of two elements that compare as equal (7.12.5.2).

— The encoding of the calendar time returned by the **time** function (7.14.2.4).

I.2 Undefined behavior

[1] The behavior in the following circumstances is undefined:

— A nonempty source file does not end in a new-line character, ends in new-line character immediately preceded by a backslash character, or ends in a partial preprocessing token or comment (5.1.1.2).

— A program contains no function called **main** (5.1.2.2.1). *

— A character not in the required character set is encountered in a source file, except in a preprocessing token that is never converted to a token, a character constant, a string literal, a header name, or a comment (5.2.1).

— A comment, string literal, character constant, or header name contains an invalid multibyte character or does not begin and end in the initial shift state (5.2.1.2).

— An unmatched **'** or **"** character is encountered on a logical source line during tokenization (6.1).

— The same identifier is used more than once as a label in the same function (6.1.2.1).

— An identifier is used that is not visible in the current scope (6.1.2.1).

— Identifiers that are intended to denote the same entity differ in a character beyond the minimal significant characters (6.1.2).

— The same identifier has both internal and external linkage in the same translation unit (6.1.2.2).

— The value stored in a pointer that referred to an object with automatic storage duration is used (6.1.2.4).

— Two declarations of the same object or function specify types that are not compatible (6.1.2.6).

— An unspecified escape sequence is encountered in a character constant or a string literal (6.1.3.4).

— An attempt is made to modify a string literal of either form (6.1.4).

— A character string literal token is adjacent to a wide string literal token (6.1.4).

— The characters **'**, ****, **"**, or **/*** are encountered between the **<** and **>** delimiters or the characters **'**, ****, or **/*** are encountered between the **"** delimiters in the two forms of a header name preprocessing token (6.1.7).

— An arithmetic conversion produces a result that cannot be represented in the space provided (6.2.1).

— An lvalue with an incomplete type is used in a context that requires the value of the designated object (6.2.2.1).

— The value of a void expression is used or an implicit conversion (except to **void**) is applied to a void expression (6.2.2.2).

— An object is modified more than once, or is modified and accessed other than to determine the new value, between two sequence points (6.3).

— An arithmetic operation is invalid (such as division or modulus by 0) or produces a result that cannot be represented in the space provided (such as overflow or underflow) (6.3).

— An object has its stored value accessed by an lvalue that does not have one of the following types: the declared type of the object, a qualified version of the declared type of the object, the signed or unsigned type corresponding to the declared type of the object, the signed or unsigned type corresponding to a qualified version of the declared type of the object, an aggregate or union type that (recursively) includes one of the aforementioned types among its members, or a character type (6.3).

— An argument to a function is a void expression (6.3.2.2).

— For a function call without a function prototype, the number of arguments does not agree with the number of parameters (6.3.2.2).

— For a function call without a function prototype, if the function is defined without a function prototype, and the types of the arguments after promotion do not agree with those of the parameters after promotion (6.3.2.2).

— If a function is called with a function prototype and the function is not defined with a compatible type (6.3.2.2).

— A function that accepts a variable number of arguments is called without a function prototype that ends with an ellipsis (6.3.2.2).

— An invalid array reference, null pointer reference, or reference to an object declared with automatic storage duration in a terminated block occurs (6.3.3.2).

— A pointer to a function is converted to point to a function of a different type and used to call a function of a type not compatible with the original type (6.3.4).

— A pointer to a function is converted to a pointer to an object or a pointer to an object is converted to a pointer to a function (6.3.4).

— A pointer is converted to other than an integral or pointer type (6.3.4).

— A pointer that does not behave like a pointer to an element of an array object is added to or subtracted from (6.3.6).

— Pointers that do not behave as if they point to the same array object are subtracted (6.3.6).

— An array subscript is out of range, even if an object is apparently accessible with the given subscript (as in the lvalue expression **a[1][7]** given the declaration **int a[4][5]**) (6.3.6). * |

— An expression is shifted by a negative number or by an amount greater than or equal to the width in bits of the expression being shifted (6.3.7).

— Pointers are compared using a relational operator that do not point to the same aggregate or union (6.3.8).

— An object is assigned to an overlapping object (6.3.16.1).

— An identifier for an object is declared with no linkage and the type of the object is incomplete after its declarator, or after its init-declarator if it has an initializer (6.5).

— A function is declared at block scope with a storage-class specifier other than **extern** (6.5.1).

— A structure or union is defined as containing only unnamed members (6.5.2.1).

— A bit-field is declared with a type other than **int**, **signed int**, or **unsigned int** (6.5.2.1).

— An attempt is made to modify an object with const-qualified type by means of an lvalue with non-const-qualified type (6.5.3).

— An attempt is made to refer to an object with volatile-qualified type by means of an lvalue with non-volatile-qualified type (6.5.3).

— A storage-class specifier or type-qualifier modifies the keyword **void** as a function parameter type list (6.5.4.3). *

— The value of an uninitialized object that has automatic storage duration is used before a value is assigned (6.5.7).

— An object with aggregate or union type with static storage duration has a non-brace-enclosed initializer, or an object with aggregate or union type with automatic storage duration has either a single expression initializer with a type other than that of the object or a non-brace-enclosed initializer (6.5.7).

— The value of a function is used, but no value was returned (6.6.6.4).

— An identifier with external linkage is used but there does not exist exactly one external definition in the program for the identifier (6.7).

— A function that accepts a variable number of arguments is defined without a parameter type list that ends with the ellipsis notation (6.7.1).

— An identifier for an object with internal linkage and an incomplete type is declared with a tentative definition (6.7.2).

— The token `defined` is generated during the expansion of a `#if` or `#elif` preprocessing directive (6.8.1).

— The `#include` preprocessing directive that results after expansion does not match one of the two header name forms (6.8.2).

— There are sequences of preprocessing tokens within the list of macro arguments that would otherwise act as preprocessing directive lines (6.8.3).

— A fully expanded macro replacement list contains a function-like macro name as its last preprocessing token (6.8.3). *

— The result of the preprocessing operator `#` is not a valid character string literal (6.8.3.2).

— The result of the preprocessing concatenation operator `##` is not a valid preprocessing token (6.8.3.3).

— The `#line` preprocessing directive that results after expansion does not match one of the two well-defined forms (6.8.4).

— One of the following identifiers is the subject of a `#define` or `#undef` preprocessing directive: `defined`, `__LINE__`, `__FILE__`, `__DATE__`, `__TIME__`, or `__STDC__` (6.8.8).

— An attempt is made to copy an object to an overlapping object by use of a library function other than `memmove` (clause 7).

— The effect if a standard header is included within an external definition; is included for the first time after the first reference to any of the functions or objects it declares, or to any of the types or macros it defines; or is included while a macro is defined with a name the same as a keyword (7.1.2).

— The effect if the program redefines a reserved external identifier (7.1.3).

— A macro definition of `errno` is suppressed to obtain access to an actual object (7.1.4).

— The parameter *member-designator* of an `offsetof` macro is an invalid right operand of the `.` operator for the *type* parameter or designates bit-field member of a structure (7.1.6).

— A library function argument has an invalid value, unless the behavior is specified explicitly (7.1.7).

— A library function that accepts a variable number of arguments is not declared (7.1.7).

— The macro definition of `assert` is suppressed to obtain access to an actual function (7.2).

— The argument to a character handling function is out of the domain (7.3).

— A macro definition of **setjmp** is suppressed to obtain access to an actual function (7.8).

— An invocation of the **setjmp** macro occurs in a context other than as the controlling expression in a selection or iteration statement, or in a comparison with an integral constant expression (possibly as implied by the unary **!** operator) as the controlling expression of a selection or iteration statement, or as an expression statement (possibly cast to **void**) (7.8.1.1).

— An object of automatic storage class that does not have volatile-qualified type has been changed between a **setjmp** invocation and a **longjmp** call and then has its value accessed (7.8.2.1).

— The **longjmp** function is invoked from a nested signal routine (7.8.2.1).

— A signal occurs other than as the result of calling the **abort** or **raise** function, and the signal handler calls any function in the standard library other than the **signal** function itself or refers to any object with static storage duration other than by assigning a value to a static storage duration variable of type **volatile sig_atomic_t** (7.9.1.1).

— The value of **errno** is referred to after a signal occurs other than as the result of calling the **abort** or **raise** function and the corresponding signal handler calls the **signal** function such that it returns the value **SIG_ERR** (7.9.1.1).

— The macro **va_arg** is invoked with the parameter **ap** that was passed to a function that invoked the macro **va_arg** with the same parameter (7.10).

— A macro definition of **va_start**, **va_arg**, or **va_end** or a combination thereof is suppressed to obtain access to an actual function (7.10.1).

— The parameter *parmN* of a **va_start** macro is declared with the **register** storage class, or with a function or array type, or with a type that is not compatible with the type that results after application of the default argument promotions (7.10.1.1).

— There is no actual next argument for a **va_arg** macro invocation (7.10.1.2).

— The type of the actual next argument in a variable argument list disagrees with the type specified by the **va_arg** macro (7.10.1.2).

— The **va_end** macro is invoked without a corresponding invocation of the **va_start** macro (7.10.1.3).

— A return occurs from a function with a variable argument list initialized by the **va_start** macro before the **va_end** macro is invoked (7.10.1.3).

— The stream for the **fflush** function points to an input stream or to an update stream in which the most recent operation was input (7.11.5.2).

— An output operation on an update stream is followed by an input operation without an intervening call to the **fflush** function or a file positioning function, or an input operation on an update stream is followed by an output operation without an intervening call to a file positioning function (7.11.5.3).

— The format for the **fprintf** or **fscanf** function does not match the argument list (7.11.6).

— An invalid conversion specification is found in the format for the **fprintf** or **fscanf** function (7.11.6).

— A **%%** conversion specification for the **fprintf** or **fscanf** function contains characters between the pair of **%** characters (7.11.6).

— A conversion specification for the **fprintf** function contains an **h** or **l** with a conversion specifier other than **d**, **i**, **n**, **o**, **u**, **x**, or **X**, or an **L** with a conversion specifier other than **e**, **E**, **f**, **g**, or **G** (7.11.6.1).

— A conversion specification for the **fprintf** function contains a **#** flag with a conversion specifier other than **o**, **x**, **X**, **e**, **E**, **f**, **g**, or **G** (7.11.6.1).

— A conversion specification for the **fprintf** function contains a **0** flag with a conversion specifier other than **d**, **i**, **o**, **u**, **x**, **X**, **e**, **E**, **f**, **g**, or **G** (7.11.6.1).

— An aggregate or union, or a pointer to an aggregate or union is an argument to the **fprintf** function, except for the conversion specifiers **%s** (for an array of character type) or **%p** (for a pointer to **void**) (7.11.6.1).

— A single conversion by the **fprintf** function produces more than 509 characters of output (7.11.6.1).

— A conversion specification for the **fscanf** function contains an **h** or **l** with a conversion specifier other than **d**, **i**, **n**, **o**, **u**, or **x**, or an **L** with a conversion specifier other than **e**, **f**, or **g** (7.11.6.2).

— A pointer value printed by **%p** conversion by the **fprintf** function during a previous program execution is the argument for **%p** conversion by the **fscanf** function (7.11.6.2).

— The result of a conversion by the **fscanf** function cannot be represented in the space provided, or the receiving object does not have an appropriate type (7.11.6.2).

— The result of converting a string to a number by the **atof**, **atoi**, or **atol** function cannot be represented (7.12.1).

— The value of a pointer that refers to space deallocated by a call to the **free** or **realloc** function is referred to (7.12.3).

— The pointer argument to the **free** or **realloc** function does not match a pointer earlier returned by **calloc**, **malloc**, or **realloc**, or the object pointed to has been deallocated by a call to **free** or **realloc** (7.12.3).

— A program executes more than one call to the **exit** function (7.12.4.3).

— The result of an integer arithmetic function (**abs**, **div**, **labs**, or **ldiv**) cannot be represented (7.12.6).

— The shift states for the **mblen**, **mbtowc**, and **wctomb** functions are not explicitly reset to the initial state when the **LC_CTYPE** category of the current locale is changed (7.12.7).

— A call to a library function exceeds an **environmental limit** (7.11.2, 7.11.3, 7.11.4.4, 7.11.6.1, 7.11.2.1).

— An array written to by a copying or concatenation function is too small (7.13.2, 7.13.3).

— An invalid conversion specification is found in the format for the **strftime** function (7.14.3.5).

I.3 Implementation-defined behavior

[1] Each implementation shall document its behavior in each of the areas listed in this subclause. The following are implementation-defined:

I.3.1 Translation

[1]

— How a diagnostic is identified (5.1.1.3).

I.3.2 Environment

[1]

— The semantics of the arguments to **main** (5.1.2.2.1).

— What constitutes an interactive device (5.1.2.3).

I.3.3 Identifiers

[1]

— The number of significant initial characters (beyond 31) in an identifier without external linkage (6.1.2).

— The number of significant initial characters (beyond 6) in an identifier with external linkage (6.1.2).

— Whether case distinctions are significant in an identifier with external linkage (6.1.2).

I.3.4 Characters

[1]

— The members of the source and execution character sets, except as explicitly specified in this International Standard (5.2.1).

— The number of bits in a character in the execution character set (5.2.4.2.1).

— The mapping of members of the source character set (in character constants and string literals) to members of the execution character set (6.1.3.4).

— The value of an integer character constant that contains a character or escape sequence not represented in the basic execution character set or the extended character set for a wide character constant (6.1.3.4).

— The value of an integer character constant that contains more than one character or a wide character constant that contains more than one multibyte character (6.1.3.4).

— The current locale used to convert multibyte characters into corresponding wide characters (codes) for a wide character constant (6.1.3.4).

— Whether a ‘‘plain’’ **`char`** has the same range of values as **`signed char`** or **`unsigned char`** (6.2.1.1).

I.3.5 Integers

[1]

— The representations and sets of values of the various types of integers (6.1.2.5).

— The result of converting an integer to a shorter signed integer, or the result of converting an unsigned integer to a signed integer of equal length, if the value cannot be represented (6.2.1.2).

— The results of bitwise operations on signed integers (6.3).

— The sign of the remainder on integer division (6.3.5).

— The result of a right shift of a negative-valued signed integral type (6.3.7).

I.3.6 Floating point

[1]

— The representations and sets of values of the various types of floating-point numbers (6.1.2.5).

— The direction of truncation when an integral number is converted to a floating-point number that cannot exactly represent the original value (6.2.1.3).

— The direction of truncation or rounding when a floating-point number is converted to a narrower floating-point number (6.2.1.4).

I.3.7 Arrays and pointers

[1]

— The type of integer required to hold the maximum size of an array — that is, the type of the **`sizeof`** operator, **`size_t`** (6.3.3.4, 7.1.1).

— The result of casting a pointer to an integer or vice versa (6.3.4).

— The type of integer required to hold the difference between two pointers to elements of the same array, **`ptrdiff_t`** (6.3.6, 7.1.1).

I.3.8 Registers

[1]

— The extent to which objects can actually be placed in registers by use of the **`register`** storage-class specifier (6.5.1).

I.3.9 Structures, unions, enumerations, and bit-fields

[1]

— A member of a union object is accessed using a member of a different type (6.3.2.3).

— The padding and alignment of members of structures (6.5.2.1). This should present no problem unless binary data written by one implementation are read by another.

— Whether a ‘‘plain’’ **`int`** bit-field is treated as a **`signed int`** bit-field or as an **`unsigned int`** bit-field (6.5.2.1).

— The order of allocation of bit-fields within a unit (6.5.2.1).

— Whether a bit-field can straddle a storage-unit boundary (6.5.2.1).

— The integer type chosen to represent the values of an enumeration type (6.5.2.2).

I.3.10 Qualifiers

— What constitutes an access to an object that has volatile-qualified type (6.5.5.3).

I.3.11 Declarators

[1]

— The maximum number of declarators that may modify an arithmetic, structure, or union type (6.5.4).

I.3.12 Statements

[1]

— The maximum number of **`case`** values in a **`switch`** statement (6.6.4.2).

I.3.13 Preprocessing directives

[1]

— Whether the value of a single-character character constant in a constant expression that controls conditional inclusion matches the value of the same character constant in the execution character set. Whether such a character constant may have a negative value (6.8.1).

— The method for locating includable source files (6.8.2).

— The support of quoted names for includable source files (6.8.2).

— The mapping of source file character sequences (6.8.2).

— The behavior on each recognized **`#pragma`** directive (6.8.6).

— The definitions for **`__DATE__`** and **`__TIME__`** when respectively, the date and time of translation are not available (6.8.8).

I.3.14 Library functions

[1]

— The null pointer constant to which the macro **`NULL`** expands (7.1.6).

— The diagnostic printed by and the termination behavior of the **`assert`** function (7.2).

— The values returned by the mathematics functions on domain errors (7.6.1).

— Whether the mathematics functions set the integer expression **`errno`** to the value of the macro **`ERANGE`** on underflow range errors (7.6.1).

— Whether a domain error occurs or zero is returned when the **`fmod`** function has a second argument of zero (7.6.6.4).

— The set of signals for the **`signal`** function (7.9.1.1).

— The semantics for each signal recognized by the **`signal`** function (7.9.1.1).

— The default handling and the handling at program startup for each signal recognized by the **`signal`** function (7.9.1.1).

— If the equivalent of **`signal(sig, SIG_DFL);`** is not executed prior to the call of a signal handler, the blocking of the signal that is performed (7.9.1.1).

— Whether the default handling is reset if the **`SIGILL`** signal is received by a handler specified to the **`signal`** function (7.9.1.1).

— Whether the last line of a text stream requires a terminating new-line character (7.11.2).

— Whether space characters that are written out to a text stream immediately before a new-line character appear when read in (7.11.2).

— The number of null characters that may be appended to data written to a binary stream (7.11.2).

— Whether the file position indicator of an append mode stream is initially positioned at the beginning or end of the file (7.11.3).

— Whether a write on a text stream causes the associated file to be truncated beyond that point (7.11.3).

— The characteristics of file buffering (7.11.3).

— Whether a zero-length file actually exists (7.11.3).

— The rules for composing valid file names (7.11.3).

— Whether the same file can be open multiple times (7.11.3).

— The effect of the **`remove`** function on an open file (7.11.4.1).

— The effect if a file with the new name exists prior to a call to the **`rename`** function (7.11.4.2).

— The output for **`%p`** conversion in the **`fprintf`** function (7.11.6.1).

— The input for **`%p`** conversion in the **`fscanf`** function (7.11.6.2).

— The interpretation of a **`-`** character that is neither the first nor the last character in the scanlist for **`%[`** conversion in the **`fscanf`** function (7.11.6.2).

— The value to which the macro **`errno`** is set by the **`fgetpos`** or **`ftell`** function on failure (7.11.9.1, 7.11.9.4).

— The messages generated by the **`perror`** function (7.11.10.4).

— The behavior of the **`calloc`**, **`malloc`**, or **`realloc`** function if the size requested is zero (7.12.3).

— The behavior of the **`abort`** function with regard to open and temporary files (7.12.4.1).

— The status returned by the **`exit`** function if the value of the argument is other than zero, **`EXIT_SUCCESS`**, or **`EXIT_FAILURE`** (7.12.4.3).

— The set of environment names and the method for altering the environment list used by the **`getenv`** function (7.12.4.4).

— The contents and mode of execution of the string by the **`system`** function (7.12.4.5).

— The local time zone and Daylight Saving Time (7.14.1).

— The era for the **`clock`** function (7.14.2.1).

I.4 Locale-specific behavior

[1] The following characteristics of a hosted environment are locale-specific and must be documented by the implementation:

— The content of the execution character set, in addition to the required members (5.2.1).

— The shift states used for the encoding of multibyte characters (5.2.1.2).

— The direction of printing (5.2.2).

— The decimal-point character (7.1.1).

— The implementation-defined aspects of character testing and case mapping functions (7.3).

— The sets of characters tested for by the **`isalnum`**, **`isalpha`**, **`iscntrl`**, **`islower`**, **`isprint`**, and **`isupper`** functions (7.3.1).

— The collation sequence of the execution character set (7.13.4.4).

— The contents of the error message strings returned by the **`strerror`** function (7.13.6.2).

— The formats for time and date (7.14.3.5).

I.5 Common extensions

[1] The following extensions are widely used in many systems, but are not portable to all implementations. The inclusion of any extension that may cause a strictly conforming program to become invalid renders an implementation nonconforming. Examples of such extensions are new keywords, or library functions declared in standard headers or predefined macros with names that do not begin with an underscore.

I.5.1 Environment arguments

[1] In a hosted environment, the **`main`** function receives a third argument, **`char *envp[]`**, that points to a null-terminated array of pointers to **`char`**, each of which points to a string that provides information about the environment for this execution of the process (5.1.2.2.1).

I.5.2 Specialized identifiers

[1] Characters other than the underscore **`_`**, letters, and digits, that are not defined in the required source character set (such as the dollar sign **`$`**, or characters in national character sets) may appear in an identifier (6.1.2).

I.5.3 Lengths and cases of identifiers

[1] All characters in identifiers (with or without external linkage) are significant and case distinctions are observed (6.1.2).

I.5.4 Scopes of identifiers

[1] A function identifier, or the identifier of an object the declaration of which contains the keyword **`extern`**, has file scope (6.1.2.1).

I.5.5 Writable string literals

[1] String literals are modifiable. Identical string literals shall be distinct (6.1.4).

I.5.6 Other arithmetic types

[1] Other arithmetic types, such as **`long long int`**, and their appropriate conversions are defined (6.2.2.1).

I.5.7 Function pointer casts

[1] A pointer to an object or to **`void`** may be cast to a pointer to a function, allowing data to be invoked as a function (6.3.4). A pointer to a function may be cast to a pointer to an object or to **`void`**, allowing a function to be inspected or modified (for example, by a debugger) (6.3.4).

I.5.8 Non-`int` bit-field types

[1] Types other than **`int`**, **`unsigned int`**, or **`signed int`** can be declared as bit-fields, with appropriate maximum widths (6.5.2.1).

I.5.9 The `fortran` keyword

[1] The **`fortran`** declaration specifier may be used in a function declaration to indicate that calls suitable for FORTRAN should be generated, or that different representations for external names are to be generated (6.5.4.3).

I.5.10 The `asm` keyword

[1] The **`asm`** keyword may be used to insert assembly language code directly into the translator output. The most common implementation is via a statement of the form

> **`asm (`** *character-string-literal* **`);`**

(6.6).

I.5.11 Multiple external definitions

[1] There may be more than one external definition for the identifier of an object, with or without the explicit use of the keyword **`extern`**, If the definitions disagree, or more than one is initialized, the behavior is undefined (6.7.2). *

I.5.12 Predefined macro names

[1] Macro names that do not begin with an underscore, describing the translation and execution environments, may be defined by the implementation before translation begins (6.8.8).

I.5.13 Extra arguments for signal handlers

[1] Handlers for specific signals may be called with extra arguments in addition to the signal number (7.9.1.1).

I.5.14 Additional stream types and file-opening modes

[1] Additional mappings from files to streams may be supported (7.11.2), and additional file-opening modes may be specified by characters appended to the **`mode`** argument of the **`fopen`** function (7.11.5.3).

I.5.15 Defined file position indicator

[1] The file position indicator is decremented by each successful call to the **`ungetc`** function for a text stream, except if its value was zero before a call (7.11.7.11).

Index

[1] Only major references are listed. [**Editor: The following index needs to be updated.**]

(Forward to be supplied by ISO Secretariat.)