The Open Group Standard

Additional APIs for the Base Specifications Issue 8, Part 1
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Additional APIs for the Base Specifications Issue 8, Part 1

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Preface

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This Document

This document has been prepared by The Open Group Base Working Group. The Open Group Base Working Group is considering submitting a number of additional APIs to the Austin Group as input to the Issue 8 revision of the Base Specifications.

This document contains the first set of these APIs.
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• The Open Group Base Working Group
• The Austin Group

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1 Introduction

1.1 Scope

The purpose of this document is to define a set of additional APIs for inclusion in the Issue 8 revision of the Base Specifications of the Single UNIX Specification.

The additional APIs proposed by participants in the Austin Group that The Open Group has agreed to sponsor are as follows:

- `dladdr()`
- `getentropy()`
- `getlocalename_l()`
- `memmem()`
- `posix_getdents()`
- `ppoll()`
- `pthread_cond_clockwait()`
- `pthread_mutex_clocklock()`
- `pthread_rwlock_clockrdlock()`
- `pthread_rwlock_clockwrlock()`
- `qsort_r()`
- `reallocarray()`
- `sem_clockwait()`
- `sig2str()`
- `str2sig()`
- `stricat()`
- `strlcpy()`
- `wcsicat()`
- `wcslcpy()`

1.2 Relationship to Other Formal Standards

This Standard is being forwarded to the Austin Group for consideration as input to the Issue 8 revision of the Base Specifications.
2 Application Program Interfaces

The following pages are extracted from a complete draft of the Base Specifications in which the proposed changes have been applied, with change bars showing the differences from Issue 8 draft 1.1. Only pages with technical changes are included – editorial changes such as additions to SEE ALSO and CHANGE HISTORY sections have been omitted (unless they appear on the same page as a technical change). The complete draft is also being made available for reference.

2.1 Change Bars

Changed lines are marked with a '|' in the right-hand margin, new lines with a '+', and deleted lines with a '-'.

Note that sometimes the placement of change bars is slightly inaccurate. In particular, changes may extend into a line following a set of change-barred lines. Also, changes within tables do not have change bars.

2.2 Reference Pages

The reference pages for the new functions and related header additions follow.
### 4.13 Memory Synchronization

Applications shall ensure that access to any memory location by more than one thread of control (threads or processes) is restricted such that no thread of control can read or modify a memory location while another thread of control may be modifying it. Such access is restricted using functions that synchronize thread execution and also synchronize memory with respect to other threads. The following functions synchronize memory with respect to other threads:

- `fork()`
- `pthread_barrier_wait()`
- `pthread_cond_broadcast()`
- `pthread_cond_clockwait()`
- `pthread_cond_signal()`
- `pthread_cond_timedwait()`
- `pthread_cond_wait()`
- `pthread_create()`
- `pthread_join()`
- `pthread_mutex_clocklock()`
- `pthread_mutex_lock()`
- `pthread_mutex_timedlock()`
- `pthread_mutex_unlock()`
- `pthread_rwlock_clockrdlock()`
- `pthread_rwlock_clockwrlock()`
- `pthread_rwlock_rdlock()`
- `pthread_rwlock_timedrdlock()`
- `pthread_rwlock_timedwrlock()`
- `pthread_rwlock_tryrdlock()`
- `pthread_rwlock_trywrlock()`
- `pthread_rwlock_unlock()`
- `pthread_rwlock_wrlock()`
- `sem_clockwait()`
- `sem_post()`
- `sem_timedwait()`
- `sem_trywait()`
- `sem_wait()`
- `semctl()`
- `semop()`
- `wait()`
- `waitpid()`

The `pthread_once()` function shall synchronize memory for the first call in each thread for a given `pthread_once_t` object. If the `init_routine` called by `pthread_once()` is a cancellation point and is canceled, a call to `pthread_once()` for the same `pthread_once_t` object made from a cancellation cleanup handler shall also synchronize memory.

The `pthread_mutex_lock()` function need not synchronize memory if the mutex type is `PTHREAD_MUTEX_RECURSIVE` and the calling thread already owns the mutex. The `pthread_mutex_unlock()` function need not synchronize memory if the mutex type is `PTHREAD_MUTEX_RECURSIVE` and the mutex has a lock count greater than one.

Unless explicitly stated otherwise, if one of the above functions returns an error, it is unspecified whether the invocation causes memory to be synchronized.

Applications may allow more than one thread of control to read a memory location simultaneously.

### 4.14 Pathname Resolution

Pathname resolution is performed for a process to resolve a pathname to a particular directory entry for a file in the file hierarchy. There may be multiple pathnames that resolve to the same directory entry, and multiple directory entries for the same file. When a process resolves a pathname of an existing directory entry, the entire pathname shall be resolved as described below. When a process resolves a pathname of a directory entry that is to be created immediately after the pathname is resolved, pathname resolution terminates when all components of the path prefix of the last component have been resolved. It is then the responsibility of the process to create the final component.

Each filename in the pathname is located in the directory specified by its predecessor (for example, in the pathname fragment `a/b`, file `b` is located in directory `a`). Pathname resolution shall fail if this cannot be accomplished. If the pathname begins with a `<slash>`, the predecessor of the first filename in the pathname shall be taken to be the root directory of the process (such pathnames are referred to as “absolute pathnames”). If the pathname does not begin with a `<slash>`, the predecessor of the first filename of the pathname shall be taken to be either the current working directory of the process or for certain interfaces the directory identified by a file
NAME
dirent.h — format of directory entries

SYNOPSIS
#include <dirent.h>

DESCRIPTION
The internal format of directories is unspecified.
The <dirent.h> header shall define the following type:

*DIR*  
A type representing a directory stream. The *DIR* type may be an incomplete type.

It shall also define the structure *dirent* which shall include the following members:

```
ino_t d_ino   File serial number.
char d_name[] Filename string of entry.
```

and the structure *posix_dent* which shall include the following members:

```
ino_t d_ino   File serial number.
reclen_t d_reclen Length of this entry, including trailing
                   padding if necessary. See *posix_getdents()*.
unsigned char d_type   File type or unknown-file-type indication.
char d_name[] Filename string of this entry.
```

The array *d_name* in each of these structures is of unspecified size, but shall contain a filename of at most *NAME_MAX* bytes followed by a terminating null byte.

The <dirent.h> header shall define the *ino_t*, *reclen_t*, *size_t*, and *ssize_t* types as described in <sys/types.h>.

The <dirent.h> header shall define the following symbolic constants for the file types and unknown-file-type indicator returned in the *d_type* member of the *posix_dent* structure. The values shall be distinct and shall be suitable for use in #if preprocessing directives:

```
DT_BLK   Block special.
DT_CHR   Character special.
DT_DIR   Directory.
DT_FIFO  FIFO special.
DT_LNK   Symbolic link.
DT_REG   Regular.
DT_SOCK  Socket.
DT_UNKNOWN Unknown file type.
```

The implementation may implement message queues, semaphores, shared memory objects or typed memory objects as distinct file types. The following macros shall be provided to represent these types. The values shall be distinct from each other and from the above symbolic constants beginning with *DT_* except when a distinct file type is not implemented, in which case the corresponding constant shall have a value that is never returned in *d_type* by *posix_getdents()*.

The values shall be suitable for use in #if preprocessing directives:

```
DT_MQ   Message queue.
```
DT_SEM  Semaphore.
    +
DT_SHM  Shared memory object.
    +
DT_TMO  Typed memory object.
    +

The following shall be declared as functions and may also be defined as macros. Function
prototypes shall be provided.

int    alphasort(const struct dirent **, const struct dirent **);
int    closedir(DIR *);
int    dirfd(DIR *);
DIR    *fdopendir(int);
DIR    *opendir(const char *);
ssize_t posix_getdents(int, void *, size_t, int);
struct dirent *readdir(DIR *);
int    readdir_r(DIR *restrict, struct dirent *restrict,
    struct dirent **restrict);
void    rewinddir(DIR *);
int    seekdir(DIR *, long);
long    telldir(DIR *);

APPLICATION USAGE
None.

RATIONALE
Information similar to that in the <dirent.h> header is contained in a file <sys/dir.h> in 4.2 BSD
and 4.3 BSD. The equivalent in these implementations of struct dirent from this volume of
POSIX.1-202x is struct direct. The filename was changed because the name <sys/dir.h> was also
used in earlier implementations to refer to definitions related to the older access method; this
produced name conflicts. The name of the structure was changed because this volume of
POSIX.1-202x does not completely define what is in the structure, so it could be different on
some implementations from struct direct.

The posix_dent structure was based on existing structures used by traditional getdents() functions, but the name was changed because the existing structures differed in name and in their members. Some used the dirent structure but this is not required to include a d_type member, which is the main advantage of using posix_getdents() over readdir(). The d_reclen member was included, even though some implementations return fixed-length entries and therefore do not need it, as almost all existing code that used getdents() used d_reclen to iterate through the returned entries. Implementations that return fixed-length entries can simply set d_reclen to that length in posix_getdents(). The type reclen_t for d_reclen was introduced, instead of using unsigned short, so as not to create a requirement that [NAME_MAX] cannot be greater than (a value somewhat smaller than) [SHRT_MAX].

Implementations are encouraged to define a DT_FORCE_TYPE symbolic constant for use in the flags argument to posix_getdents(). See the RATIONALE for posix_getdents().

The name of an array of char of an unspecified size should not be used as an lvalue. Use of:

sizeof(d_name)
is incorrect; use:
\begin{verbatim}
strlen(d_name)
\end{verbatim}

instead.

The array of \texttt{char} \texttt{d_name} cannot be assumed to have a fixed size. Implementations may define
the \texttt{d_name} array in the \texttt{dirent} and \texttt{posix_dent} structures to have size 1, or size greater than
\texttt{Name_MAX}, or use a flexible array member, but in all cases the actual number of characters
used for \texttt{d_name} is at least the length of the filename string including the terminating NUL byte.

\begin{small}
\textbf{FUTURE DIRECTIONS}
A future version of this standard may add a DT_FORCE_TYPE symbolic constant for use as
\begin{small}
\texttt{DT\_FORCE\_TYPE}
\end{small}
described in the RATIONALE for \texttt{posix_getdents()}.\end{small}

\begin{small}
\textbf{SEE ALSO}
\begin{small}
\texttt{<sys/types.h>}
\end{small}
\texttt{XSH alphasort()}, \texttt{closedir()}, \texttt{dirfd()}, \texttt{fdopendir()}, \texttt{posix_getdents()}, \texttt{readdir()}, \texttt{rewinddir()}, \texttt{seekdir()}, +
\texttt{telldir()}
\end{small}

\begin{small}
\textbf{CHANGE HISTORY}
First released in Issue 2.
\end{small}

\begin{small}
\textbf{Issue 5}
The DESCRIPTION is updated for alignment with the POSIX Threads Extension.
\end{small}

\begin{small}
\textbf{Issue 6}
The Open Group Corrigendum U026/7 is applied, correcting the prototype for \texttt{readdir\_r()}. The \texttt{restrict} keyword is added to the prototype for \texttt{readdir\_r()}.\end{small}

\begin{small}
\textbf{Issue 7}
The \texttt{alphasort()}, \texttt{dirfd()}, and \texttt{scandir()} functions are added from The Open Group Technical
Standard, 2006, Extended API Set Part 1. The \texttt{fdopendir()} function is added from The Open Group Technical Standard, 2006, Extended API
Set Part 2. Austin Group Interpretation 1003.1-2001 #110 is applied, clarifying the definition of the \texttt{DIR}
type. POSIX.1-2008, Technical Corrigendum 1, XBD/TC1-2008/0039 [291], XBD/TC1-2008/0040 [291],
XBD/TC1-2008/0041 [291], and XBD/TC1-2008/0042 [206] are applied. +
\end{small}

\begin{small}
\textbf{Issue 8}
Austin Group Defect 697 is applied, adding \texttt{posix_getdents()}.\end{small}
NAME
dlfcn.h — dynamic linking

SYNOPSIS
#include <dlfcn.h>

DESCRIPTION
The <dlfcn.h> header shall define the DL_info_t structure type, which shall include at least the following members:

const char *dli_fname Pathname of mapped object file.
void *dli_fbase Base of mapped address range.
const char *dli_sname Symbol name or null pointer.
void *dli_saddr Symbol address or null pointer.

The <dlfcn.h> header shall define at least the following symbolic constants for use in the construction of a dlopen() mode argument:

RTLD_LAZY Relocations are performed at an implementation-defined time.
RTLD_NOW Relocations are performed when the object is loaded.
RTLD_GLOBAL All symbols are available for relocation processing of other modules.
RTLD_LOCAL All symbols are not made available for relocation processing by other modules.

The following shall be declared as functions and may also be defined as macros. Function prototypes shall be provided.

int dladdr(const void *restrict, DL_info_t *restrict);
int dlclose(void *);
char *dlerror(void);
void *dlopen(const char *, int);
void *dlsym(void *, const char *restrict, const char *restrict);

APPLICATION USAGE
None.

RATIONALE
None.

FUTURE DIRECTIONS
None.

SEE ALSO
XSH dladdr(), dlclose(), dlerror(), dlopen(), dlsym()

CHANGE HISTORY
First released in Issue 5.

Issue 6
The restrict keyword is added to the prototype for dlsym().

Issue 7
The <dlfcn.h> header is moved from the XSI option to the Base.

This reference page is clarified with respect to macros and symbolic constants.
Other Invariant Values

The `<limits.h>` header shall define the following symbolic constants:

- `{GETENTROPY_MAX}`
  - The maximum value of the `length` argument in calls to the `getentropy()` function.
  - Minimum Acceptable Value: 256

- `{NL_ARGMAX}`
  - Maximum value of `n` in conversion specifications using the `"%n$"` sequence in calls to the `printf()` and `scanf()` families of functions.
  - Minimum Acceptable Value: 9

- `{NL_LANGMAX}`
  - Maximum number of bytes in a `LANG` name.
  - Minimum Acceptable Value: 14

- `{NL_MSGMAX}`
  - Maximum message number.
  - Minimum Acceptable Value: 32,767

- `{NL_SETMAX}`
  - Maximum set number.
  - Minimum Acceptable Value: 255

- `{NL_TEXTMAX}`
  - Maximum number of bytes in a message string.
  - Minimum Acceptable Value: `_POSIX2_LINE_MAX`

- `{NSIG_MAX}`
  - Maximum possible return value of `sysconf(_SC_NSIG)`. See XSH `sysconf()`. The value of `{NSIG_MAX}` shall be no greater than the number of signals that the `sigset_t` type (see `<signal.h>`) is capable of representing, ignoring any restrictions imposed by `sigfillset()` or `sigaddset()`.

- `{NZERO}`
  - Default process priority.
  - Minimum Acceptable Value: 20

APPLICATION USAGE

None.

RATIONALE

A request was made to reduce the value of `{_POSIX_LINK_MAX}` from the value of 8 specified for it in the POSIX.1-1990 standard to 2. The standard developers decided to deny this request for several reasons:

- They wanted to avoid making any changes to the standard that could break conforming applications, and the requested change could have that effect.

- The use of multiple hard links to a file cannot always be replaced with use of symbolic links. Symbolic links are semantically different from hard links in that they associate a pathname with another pathname rather than a pathname with a file. This has implications for access control, file permanence, and transparency.

- The original standard developers had considered the issue of allowing for implementations that did not in general support hard links, and decided that this would reduce consensus on the standard.
The `<locale.h>` header shall contain at least the following macros representing bitmasks for use with the `newlocale()` function for each supported locale category:

- `LC_COLLATE_MASK`
- `LC_CTYPE_MASK`
- `LC_MESSAGES_MASK`
- `LC_MONETARY_MASK`
- `LC_NUMERIC_MASK`
- `LC_TIME_MASK`

In addition, a macro to set the bits for all categories set shall be defined:

- `LC_ALL_MASK`

The `<locale.h>` header shall define `LC_GLOBAL_LOCALE`, a special locale object descriptor used by the `duplocale()` and `uselocale()` functions.

The `<locale.h>` header shall define the `locale_t` type, representing a locale object.

The following shall be declared as functions and may also be defined as macros. Function prototypes shall be provided for use with ISO C standard compilers.

```c
locale_t duplocale(locale_t);
void freelocale(locale_t);
const char *getlocalename_l(int, locale_t);
struct lconv *localeconv(void);
locale_t newlocale(int, const char *, locale_t);
char *setlocale(int, const char *);
locale_t uselocale (locale_t);
```

**APPLICATION USAGE**

None.

**RATIONALE**

It is suggested that each category macro name for use in `setlocale()` have a corresponding macro name ending in `_MASK` for use in `newlocale()`.

**FUTURE DIRECTIONS**

None.

**SEE ALSO**

- Chapter 8 (on page 153), `<stddef.h>`
- XSH `duplocale()`, `freelocale()`, `getlocalename_l()`, `localeconv()`, `newlocale()`, `setlocale()`, `uselocale()`

**CHANGE HISTORY**

First released in Issue 3.

Included for alignment with the ISO C standard.

**Issue 6**

The `lconv` structure is expanded with new members (`int n_cs_precedes`, `int n_sep_by_space`, `int n_sign_posn`, `int p_cs_precedes`, `int p_sep_by_space`, and `int p_sign_posn`) for alignment with the ISO/IEC 9899: 1999 standard.

Extensions beyond the ISO C standard are marked.
NAME
poll.h — definitions for the poll() function

SYNOPSIS
#include <poll.h>

DESCRIPTION
The <poll.h> header shall define the pollfd structure, which shall include at least the following members:

- int fd  The following descriptor being polled.
- short events  The input event flags (see below).
- short revents  The output event flags (see below).

The <poll.h> header shall define the following type through typedef:

- nfds_t  An unsigned integer type used for the number of file descriptors.

The implementation shall support one or more programming environments in which the width of nfds_t is no greater than the width of type long. The names of these programming environments can be obtained using the confstr() function or the getconf utility.

The <poll.h> header shall define the sigset_t type as described in <signal.h>.

The <poll.h> header shall define the timespec structure as described in <time.h>.

The <poll.h> header shall define the following symbolic constants, zero or more of which may be OR’ed together to form the events or revents members in the pollfd structure:

- POLLIN  Data other than high-priority data may be read without blocking.
- POLLRDNORM  Normal data may be read without blocking.
- POLLRBAND  Priority data may be read without blocking.
- POLLPRI  High priority data may be read without blocking.
- POLLOUT  Normal data may be written without blocking.
- POLLWNRNORM  Equivalent to POLLOUT.
- POLLWRBAND  Priority data may be written.
- POLLERR  An error has occurred (revents only).
- POLLHUP  Device has been disconnected (revents only).
- POLLNVAL  Invalid fd member (revents only).

The significance and semantics of normal, priority, and high-priority data are file and device-specific.

The following shall be declared as functions and may also be defined as macros. Function prototypes shall be provided.

- int poll(struct pollfd [], nfds_t, int);
- int ppoll(struct pollfd [], nfds_t, const struct timespec *restrict,
  const sigset_t *restrict);

Inclusion of the <poll.h> header may make visible all symbols from the headers <signal.h> and <time.h>.
```c
int pthread_atfork(void (*)(void), void (*)(void), void (*)(void));
int pthread_attr_destroy(pthread_attr_t *);
int pthread_attr_getdetachstate(const pthread_attr_t *, int *);
int pthread_attr_getguardsize(const pthread_attr_t *restrict, size_t *restrict);
int pthread_attr_getinheritsched(const pthread_attr_t *restrict, int *restrict);
int pthread_attr_getschedpolicy(const pthread_attr_t *restrict, int *restrict);
int pthread_attr_getscope(const pthread_attr_t *restrict, int *restrict);
int pthread_attr_init(pthread_attr_t *);
int pthread_attr_setdetachstate(pthread_attr_t *, int);
int pthread_attr_setguardsize(pthread_attr_t *, size_t);
int pthread_attr_setschedparam(pthread_attr_t *, const struct sched_param *restrict);
int pthread_attr_setschedpolicy(pthread_attr_t *, int);
int pthread_attr_setscope(pthread_attr_t *, int);
int pthread_attr_setstack(pthread_attr_t *, void *, size_t);
int pthread_attr_setstacksize(pthread_attr_t *, size_t);
int pthread_barrier_destroy(pthread_barrier_t *);
int pthread_barrier_init(pthread_barrier_t *restrict, const pthread_barrierattr_t *restrict, unsigned);
int pthread_barrierattr_destroy(pthread_barrierattr_t *);
int pthread_barrierattr_getpshared(const pthread_barrierattr_t *restrict, int *restrict);
int pthread_barrierattr_init(pthread_barrierattr_t *);
int pthread_barrierattr_setpshared(pthread_barrierattr_t *, int);
int pthread_barrierattr_setown(void *, size_t);
int pthread_barrierattr_setshared(const pthread_barrierattr_t *restrict, int *restrict);
int pthread_cancel(pthread_t);
int pthread_cond_broadcast(pthread_cond_t *);
int pthread_cond_clockwait(pthread_cond_t *restrict, const struct timespec *restrict, pthread_mutex_t *restrict, clockid_t, const struct timespec *restrict);
int pthread_cond_destroy(pthread_cond_t *);
int pthread_cond_init(pthread_cond_t *restrict, const pthread_condattr_t *restrict);
int pthread_cond_signal(pthread_cond_t *);
int pthread_cond_timedwait(pthread_cond_t *restrict, const struct timespec *restrict, pthread_mutex_t *restrict);
int pthread_cond_wait(pthread_cond_t *restrict, pthread_mutex_t *restrict);
int pthread_condattr_destroy(pthread_condattr_t *);
int pthread_condattr_getclock(const pthread_condattr_t *restrict, clockid_t *restrict);
int pthread_condattr_getpshared(const pthread_condattr_t *restrict, int *restrict);
int pthread_condattr_init(pthread_condattr_t *);
int pthread_condattr_setclock(const pthread_condattr_t *, clockid_t);
int pthread_condattr_setpshared(pthread_condattr_t *, int);
int pthread_condattr_setowns(void *, size_t);
int pthread_condattr_setscope(const pthread_condattr_t *, int);
int pthread_condattr_settime(const pthread_condattr_t *, const struct timespec *restrict);
```
clockid_t *restrict);

int pthread_condattr_getpshared(const pthread_condattr_t *restrict,
int *restrict);
int pthread_condattr_init(pthread_condattr_t * restrict, clockid_t);
int pthread_condattr_setclock(pthread_condattr_t * restrict, int);
int pthread_create(pthread_t * restrict, const pthread_attr_t * restrict,
void *(*)(void*), void * restrict);

int pthread_detach(pthread_t);
int pthread_equal(pthread_t, pthread_t);
void pthread_exit(void *);

int pthread_getcpuclockid(pthread_t, clockid_t *);
int pthread_getschedparam(pthread_t, int * restrict,
struct sched_param * restrict);

void *pthread_getspecific(pthread_key_t);

int pthread_join(pthread_t, void **);
int pthread_key_create(pthread_key_t *, void (*)(void*));
int pthread_key_delete(pthread_key_t);

int pthread_mutex_clocklock(pthread_mutex_t* restrict, clockid_t, +
const struct timespec * restrict);
int pthread_mutex_consistent(pthread_mutex_t *);
int pthread_mutex_destroy(pthread_mutex_t *);

int pthread_mutex_getprioceiling(const pthread_mutex_t *restrict,
int *restrict);
int pthread_mutex_init(pthread_mutex_t *restrict,
const pthread_mutexattr_t * restrict);
int pthread_mutex_lock(pthread_mutex_t *);

int pthread_mutex_setprioceiling(pthread_mutex_t * restrict, int,
int * restrict);
int pthread_mutex_timedlock(pthread_mutex_t * restrict,
const struct timespec * restrict);

int pthread_mutex_trylock(pthread_mutex_t *);
int pthread_mutex_unlock(pthread_mutex_t *);
int pthread_mutexattr_destroy(pthread_mutexattr_t *);

int pthread_mutexattr_getprioceiling(const pthread_mutexattr_t *restrict,
int *restrict);
int pthread_mutexattr_getprotocol(const pthread_mutexattr_t *restrict,
int *restrict);
int pthread_mutexattr_getpshared(const pthread_mutexattr_t *restrict,
int *restrict);
int pthread_mutexattr_getrobust(const pthread_mutexattr_t *restrict,
int *restrict);
int pthread_mutexattr_gettype(const pthread_mutexattr_t *restrict,
int *restrict);

int pthread_mutexattr_init(pthread_mutexattr_t *);

int pthread_mutexattr_setprioceiling(pthread_mutexattr_t *, int);
int pthread_mutexattr_setprotocol(pthread_mutexattr_t *, int);
int pthread_mutexattr_setpshared(pthread_mutexattr_t *, int);
int pthread_mutexattr_setrobust(pthread_mutexattr_t *, int);

int pthread_once(pthread_once_t *, void (*)(void*));
int pthread_rwlock_destroy(pthread_rwlock_t *);
The following may be declared as functions, or defined as macros, or both. If functions are declared, function prototypes shall be provided.

\[ \text{pthread_cleanup_pop()} \]
\[ \text{pthread_cleanup_push()} \]

Inclusion of the `<pthread.h>` header shall make symbols defined in the headers `<sched.h>` and `<time.h>` visible.
NAME

semaphore.h — semaphores

SYNOPSIS

#include <semaphore.h>

DESCRIPTION

The <semaphore.h> header shall define the sem_t type, used in performing semaphore operations. The semaphore may be implemented using a file descriptor, in which case applications are able to open up at least a total of {OPEN_MAX} files and semaphores.

The <semaphore.h> header shall define the timespec structure as described in <time.h>.

The <semaphore.h> header shall define the symbolic constant SEM_FAILED which shall have type sem_t*.

The <semaphore.h> header shall define O_CREAT and O_EXCL as described in <fcntl.h>.

The following shall be declared as functions and may also be defined as macros. Function prototypes shall be provided.

int sem_clockwait(sem_t *restrict, clockid_t, +
       const struct timespec *restrict); +
int sem_close(sem_t *);
int sem_destroy(sem_t *);
int sem_getvalue(sem_t *restrict, int *restrict);
int sem_init(sem_t *, int, unsigned);
sem_t *sem_open(const char *, int, ...);
int sem_post(sem_t *);
int sem_timedwait(sem_t *restrict, const struct timespec *restrict);
int sem_trywait(sem_t *);
int sem_unlink(const char *);
int sem_wait(sem_t *);

Inclusion of the <semaphore.h> header may make visible symbols defined in the <fcntl.h> and <time.h> headers.

APPLICATION USAGE

None.

RATIONALE

None.

FUTURE DIRECTIONS

None.

SEE ALSO

<fcntl.h>, <sys/types.h>, <time.h>

XSH sem_close(), sem_destroy(), sem_getvalue(), sem_init(), sem_open(), sem_post(),
sem_timedwait(), sem_trywait(), sem_unlink()

CHANGE HISTORY

First released in Issue 5. Included for alignment with the POSIX Realtime Extension.

Issue 6

The <semaphore.h> header is marked as part of the Semaphores option.

The Open Group Corrigendum U021/3 is applied, adding a description of SEM_FAILED.

The sem_timedwait() function is added for alignment with IEEE Std 1003.1d-1999.
The `signal.h` header shall declare the SIGRTMIN and SIGRTMAX macros, which shall expand to positive integer expressions with type `int`, but which need not be constant expressions. These macros specify a range of signal numbers that are reserved for application use and for which the realtime signal behavior specified in this volume of POSIX.1-202x is supported. The signal numbers in this range do not overlap any of the signals specified in the following table.

The range SIGRTMIN through SIGRTMAX inclusive shall include at least `RTSIG_MAX` signal numbers. The value of SIGRTMAX shall be less than the value returned by `sysconf(_SC_NSIG)`.

It is implementation-defined whether realtime signal behavior is supported for other signals.

The `signal.h` header shall define the following symbolic constant. The value shall be suitable for use in `#if` preprocessing directives:

```
SIG2STR_MAX Maximum size of a signal name returned by sig2str(), including the terminating null byte.
```

The `signal.h` header shall define the following macros that are used to refer to the signals that occur in the system. Signals defined here begin with the letters SIG followed by an uppercase letter. The macros shall expand to positive integer constant expressions with type `int` and distinct values less than the value of `NSIG_MAX` defined in `<limits.h>`. The value 0 is reserved for use as the null signal (see `kill()`). Additional implementation-defined signals may occur in the system.

The ISO C standard only requires the signal names SIGABRT, SIGFPE, SIGILL, SIGINT, SIGSEGV, and SIGTERM to be defined. An implementation need not generate any of these six signals, except as a result of explicit use of interfaces that generate signals, such as `raise()`, `kill()`, the General Terminal Interface (see Section 11.1.9, on page 185), and the `kill` utility, unless otherwise stated (see, for example, XSH Section 2.8.3.3, on page 491).

The following signals shall be supported on all implementations (default actions are explained below the table):

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGABRT</td>
<td>Abort signal</td>
</tr>
<tr>
<td>SIGFPE</td>
<td>Floating-point exception signal</td>
</tr>
<tr>
<td>SIGILL</td>
<td>Invalid signal</td>
</tr>
<tr>
<td>SIGINT</td>
<td>Interrupt signal</td>
</tr>
<tr>
<td>SIGSEGV</td>
<td>Segmentation fault signal</td>
</tr>
<tr>
<td>SIGTERM</td>
<td>Termination signal</td>
</tr>
</tbody>
</table>
In addition, the following signal-specific information shall be available:

<table>
<thead>
<tr>
<th>Signal</th>
<th>Member</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGILL</td>
<td>void *si_addr</td>
<td>Address of faulting instruction.</td>
</tr>
<tr>
<td>SIGFPE</td>
<td>void *si_addr</td>
<td>Address of faulting memory reference.</td>
</tr>
<tr>
<td>SIGSEGV</td>
<td>pid_t si_pid</td>
<td>Child process ID.</td>
</tr>
<tr>
<td>SIGBUS</td>
<td>int si_status</td>
<td>If si_code is equal to CLD_EXITED, then si_status holds the exit value of the process; otherwise, it is equal to the signal that caused the process to change state. The exit value in si_status shall be equal to the full exit value (that is, the value passed to _exit(), _Exit(), or exit(), or returned from main()); it shall not be limited to the least significant eight bits of the value. Real user ID of the process that sent the signal.</td>
</tr>
</tbody>
</table>

For some implementations, the value of *si_addr may be inaccurate.

The following shall be declared as functions and may also be defined as macros. Function prototypes shall be provided.

```c
int kill(pid_t, int);
int killpg(pid_t, int);
void psiginfo(const siginfo_t *, const char *);
void psignal(int, const char *);
int pthread_kill(pthread_t, int);
int pthread_sigmask(int, const sigset_t *restrict, sigset_t *restrict);
int raise(int);
int sig2str(int, char *);
int sigaction(int, const struct sigaction *restrict, struct sigaction *restrict);
int sigaddset(sigset_t *, int);
int sigaltstack(const stack_t *restrict, stack_t *restrict);
int sigdelset(sigset_t *, int);
int sigemptyset(sigset_t *);
int sigfillset(sigset_t *);
int sigismember(const sigset_t *, int);
void (*signal(int, void (*)(int)))(int);
int sigpending(sigset_t *);
int sigprocmask(int, const sigset_t *restrict, sigset_t *restrict);
int sigqueue(pid_t, int, union sigval);
int sigsuspend(const sigset_t *);
int sigtimedwait(const sigset_t *restrict, siginfo_t *restrict, const struct timespec *restrict);
int sigwait(const sigset_t *restrict, int *restrict);
int sigwaitinfo(const sigset_t *restrict, siginfo_t *restrict);
int str2sig(const char *restrict, int *restrict);
```

Inclusion of the `<signal.h>` header may make visible all symbols from the `<time.h>` header.
Inclusion of the `<stdlib.h>` header may also make visible all symbols from `<fcntl.h>`, `<limits.h>`, `<math.h>`, `<stddef.h>`, and `<sys/wait.h>`.

APPLICATION USAGE

None.

RATIONALE

The ISO C standard requires that `exit(EXIT_FAILURE)` returns "unsuccessful termination status" to the host environment. In a POSIX host environment this means that the lower 8 bits of EXIT_FAILURE must have at least one bit set. The standard developers decided to further restrict the allowed values for the following reasons:

- Exit statuses of 126, 127, and greater than 128 are ambiguous in certain circumstances because they have special meanings in the shell (see XCU Section 2.8.2, on page 2321).
- The `xargs` utility quits when a command execution exits with status 255 (see XCU `xargs`).
- Calling `exit()` with a value greater than 255 or less than 0 is something that only programs which are specifically designed to have their exit status obtained by `waitid()` should do (since it does not truncate the exit status to 8 bits). "Pure ISO C" programs that call `exit(EXIT_FAILURE)` do not meet this design criterion.
NAME
string.h — string operations

SYNOPSIS
#include <string.h>

DESCRIPTION
Some of the functionality described on this reference page extends the ISO C standard. Applications shall define the appropriate feature test macro (see XSH Section 2.2, on page 460) to enable the visibility of these symbols in this header.

The <string.h> header shall define NULL and size_t as described in <stddef.h>.

The <string.h> header shall define the locale_t type as described in <locale.h>.

The following shall be declared as functions and may also be defined as macros. Function prototypes shall be provided for use with ISO C standard compilers.

XSI
void *memccpy(void *restrict, const void *restrict, int, size_t);
void *memchr(const void *, int, size_t);
int memcmp(const void *, const void *, size_t);
void *memcpy(void *restrict, const void *restrict, size_t);
CX
void *memmem(const void *, size_t, const void *, size_t);
void *memmove(void *, const void *, size_t);
void *memset(void *, int, size_t);
CX
char *strpcpy(char *restrict, const char *restrict);
char *strncpy(char *restrict, const char *restrict, size_t);
<sys/types.h>

- pthread_t Used to identify a thread.
- reclen_t Used for directory entry lengths.
- size_t Used for sizes of objects.
- ssize_t Used for a count of bytes or an error indication.
- suseconds_t Used for time in microseconds.
- time_t Used for time in seconds.
- timer_t Used for timer ID returned by timer_create().
- uid_t Used for user IDs.

All of the types shall be defined as arithmetic types of an appropriate length, with the following exceptions:

- pthread_attr_t
- pthread_barrier_t
- pthread_barrierattr_t
- pthread_cond_t
- pthread_condattr_t
- pthread_key_t
- pthread_mutex_t
- pthread_mutexattr_t
- pthread_once_t
- pthread_rwlock_t
- pthread_rwlockattr_t
- pthread_spinlock_t
- pthread_t
- timer_t

Additionally:

- mode_t shall be an integer type.
- dev_t shall be an integer type.
- nlink_t, uid_t, gid_t, and id_t shall be integer types.
- blkcnt_t and off_t shall be signed integer types.
- fsblkcnt_t, fsfilcnt_t, reclen_t, and ino_t shall be defined as unsigned integer types.
- size_t shall be an unsigned integer type.
- blksize_t, pid_t, and ssize_t shall be signed integer types.
- clock_t shall be an integer or real-floating type. time_t shall be an integer type.

The type ssize_t shall be capable of storing values at least in the range $[-1, \text{SSIZE_MAX}]$. The type suseconds_t shall be a signed integer type capable of storing values at least in the range $[-1, 1\,000\,000]$. The implementation shall support one or more programming environments in which the widths of blksize_t, pid_t, size_t, ssize_t, and suseconds_t are no greater than the width of type long. The names of these programming environments can be obtained using the confstr() function or the getconf utility.

There are no defined comparison or assignment operators for the following types:
int dup2(int, int);
int dup3(int, int, int);
void _exit(int);

OB XSI void encrypt(char [64], int);

int execl(const char *, const char *, ...);
int execlp(const char *, const char *, ...);
int execv(const char *, char *const []);
int execve(const char *, char *const [], char *const []);
int facessat(int, const char *, int, int);
int fchdir(int);
int fchown(int, uid_t, gid_t);
int fchownat(int, const char *, uid_t, gid_t, int);

SIO int fdatasync(int);
int fexecve(int, char *const [], char *const []);
pid_t _Fork(void);
pid_t fork(void);
long fpathconf(int, int);

FSC int fsync(int);
int ftruncate(int, off_t);
char *getcwd(char *, size_t);
gid_t getegid(void);
int getentropy(void *, size_t);
uid_t geteuid(void);
gid_t getgid(void);
int getgroups(int, gid_t []);

XSI long gethostid(void);
int gethostname(char *, size_t);
char *getlogin(void);
int getlogin_r(char *, size_t);
int getopt(int, char * const [], const char *);
pid_t getpgid(pid_t);
pid_t getpid(void);

XSI int getpgrp(void);
int getppid(void);
pid_t getsid(pid_t);
uid_t getuid(void);

int isatty(int);
int lchown(const char *, uid_t, gid_t);
int link(const char *, const char *);
int linkat(int, const char *, int, const char *, int);

XSI int lockf(int, int, off_t);
off_t lseek(int, off_t, int);

XSI int nice(int);
long pathconf(const char *, int);
int pause(void);
int pipe(int [2]);
int pipe2(int [2], int);
int posix_close(int, int);

ssize_t pread(int, void *, size_t, off_t);
ssize_t pwrite(int, const void *, size_t, off_t);
int fputws(const wchar_t *restrict, FILE *restrict);

int fwide(FILE *, int);

int fprintf(FILE *restrict, const wchar_t *restrict, ...);

int fscanf(FILE *restrict, const wchar_t *restrict, ...);

wint_t getwc(FILE *);

wint_t getwchar(void);

size_t mbrelen(const char *restrict, size_t, mbstate_t *restrict);

size_t mbstowcs(wchar_t *restrict, const char *restrict, size_t, mbstate_t *restrict);

int mbsinit(const mbstate_t *);

size_t mbsnrtowcs(wchar_t *restrict, const char **restrict, size_t, mbstate_t *restrict);

size_t mbsrtowcs(wchar_t *restrict, const char **restrict, size_t, mbstate_t *restrict);

FILE *open_wmemstream(wchar_t **, size_t *);

wint_t putwc(wchar_t, FILE *);

wint_t putwchar(wchar_t);

int swprintf(wchar_t*restrict, size_t, const wchar_t *restrict, ...);

int swscanf(const wchar_t *restrict, const wchar_t *restrict, ...);

wint_t ungetwc(wint_t, FILE *);

int vfwprintf(FILE *restrict, const wchar_t *restrict, va_list);

int vfwscanf(FILE *restrict, const wchar_t *restrict, va_list);

int vswprintf(wchar_t *restrict, size_t, const wchar_t *restrict, va_list);

int vswscanf(const wchar_t *restrict, const wchar_t *restrict, va_list);

int vwprintf(const wchar_t *restrict, va_list);

int vwscanf(const wchar_t *restrict, va_list);

wchar_t *wcpcpy(wchar_t *restrict, const wchar_t *restrict);

wchar_t *wcpncpy(wchar_t *restrict, const wchar_t *restrict, size_t);

size_t wcrtomb(char *restrict, wchar_t, mbstate_t *restrict);

int wcscasecmp(const wchar_t *, const wchar_t *);

int wcscasecmp_l(const wchar_t *, const wchar_t *, locale_t);

wchar_t *wcscat(wchar_t *restrict, const wchar_t *restrict);

wchar_t *wcschr(const wchar_t *, wchar_t *);

int wcscmp(const wchar_t *, const wchar_t *);

int wcscoll(const wchar_t *, const wchar_t *);

int wcscoll_l(const wchar_t *, const wchar_t *, locale_t);

wchar_t *wcsncpy(wchar_t *restrict, const wchar_t *restrict);

size_t wcsccspn(const wchar_t *, const wchar_t *);

size_t wcsdup(const wchar_t *);

size_t wcsftime(wchar_t *restrict, size_t, const wchar_t *restrict, const struct tm *restrict);

size_t wcsicmp(const wchar_t *, const wchar_t *);

size_t wcsncmp(const wchar_t *, const wchar_t *, size_t);

size_t wcscspn(const wchar_t *, const wchar_t *);

size_t wcslcat(const wchar_t *, const wchar_t *, size_t);

size_t wcslcpy(const wchar_t *, const wchar_t *, size_t);

size_t wcslen(const wchar_t *);

int wcscasecmp(const wchar_t *, const wchar_t *, size_t);

int wcscasecmp_l(const wchar_t *, const wchar_t *, size_t,
<table>
<thead>
<tr>
<th>Header</th>
<th>Prefix</th>
<th>Suffix</th>
<th>Complete Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;aio.h&gt;</td>
<td>aio_, lio_, AIO_, LIO_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;arpa/inet.h&gt;</td>
<td>inet_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;ctype.h&gt;</td>
<td>to[a-z], is[a-z]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;dlfcn.h&gt;</td>
<td>RTLD_, dli_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;dirent.h&gt;</td>
<td>d_, DT_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;fcntl.h&gt;</td>
<td>_</td>
<td>l_</td>
<td></td>
</tr>
<tr>
<td>&lt;fmtmsg.h&gt;</td>
<td>MM_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;fnmatch.h&gt;</td>
<td>FNM_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;ftw.h&gt;</td>
<td>FTW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;glob.h&gt;</td>
<td>gl_, GLOB_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;grp.h&gt;</td>
<td>gr_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;limits.h&gt;</td>
<td></td>
<td>MAX, MIN</td>
<td></td>
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<tr>
<td>&lt;math.h&gt;</td>
<td>M_</td>
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</tr>
<tr>
<td>&lt;mqueue.h&gt;</td>
<td>mq_, MQ_</td>
<td></td>
<td></td>
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<tr>
<td>&lt;ndbm.h&gt;</td>
<td>dbm_, DBM_</td>
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<tr>
<td>&lt;netdb.h&gt;</td>
<td>ai_ h_, n_, p_, s_</td>
<td></td>
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<tr>
<td>&lt;net/if.h&gt;</td>
<td>if_, IF_</td>
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<td></td>
</tr>
<tr>
<td>&lt;netinet/in.h&gt;</td>
<td>in_, ip_, s_, sin_, INADDR_, IPPROTO_, in6_, in6addr_, s6_, sin6_, IPV6_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;netinet/tcp.h&gt;</td>
<td>TCP_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;netinet/tcp.h&gt;</td>
<td>NL_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;poll.h&gt;</td>
<td>pd_, ph_, ps_, POLL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;pthread.h&gt;</td>
<td>pthread_, PTHREAD_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;pwd.h&gt;</td>
<td>pw_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;regex.h&gt;</td>
<td>re_, rm_, REG_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;sched.h&gt;</td>
<td>sched_, SCHED_</td>
<td></td>
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<tr>
<td>&lt;semaphore.h&gt;</td>
<td>sem_, SEM_</td>
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<tr>
<td>&lt;signal.h&gt;</td>
<td>sa_, si_, sigev_, sival_, uc_, BUS_, CLD_, FPE_, ILL_, SA_, SEGV_, SI_, SIGEV_, ss_, sv_, SS_, TRAP_</td>
<td></td>
<td></td>
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<tr>
<td>&lt;signal.h&gt;</td>
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<td>&lt;signal.h&gt;</td>
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</tr>
<tr>
<td>&lt;stdlib.h&gt;</td>
<td>str[a-z]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;string.h&gt;</td>
<td>str[a-z], mem[a-z], wcs[a-z]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;sys/ipc.h&gt;</td>
<td>ipc_, IPC_</td>
<td>key, pad, seq</td>
<td></td>
</tr>
<tr>
<td>&lt;sys/mman.h&gt;</td>
<td>shm_, MAP_, MCL_, MS_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;sys/resource.h&gt;</td>
<td>rlim_, ru_, PRIO_, RLIMIT_, RUSAGE_</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;sys/select.h&gt;</td>
<td>fd_, fds_, FD_</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sanity Review

General Information

Signal Concepts
If a thread is detached, its thread ID is invalid for use as an argument in a call to `pthread_detach()` or `pthread_join()`.

### 2.9.3 Thread Mutexes

A thread that has blocked shall not prevent any unblocked thread that is eligible to use the same processing resources from eventually making forward progress in its execution. Eligibility for processing resources is determined by the scheduling policy.

A thread shall become the owner of a mutex, `m`, when one of the following occurs:

- It calls `pthread_mutex_clocklock()`, `pthread_mutex_lock()`, `pthread_mutex_timedlock()`, or `pthread_mutex_trylock()` with `m` as the `mutex` argument and the call returns zero or [EOWNERDEAD].
- It calls `pthread_mutex_setprioceiling()` with `m` as the `mutex` argument and the call returns - [EOWNERDEAD].
- It calls `pthread_cond_clockwait()`, `pthread_cond_timedwait()`, or `pthread_cond_wait()` with `m` as the `mutex` argument and the call returns zero or certain error numbers (see `pthread_cond_timedwait()`).

The thread shall remain the owner of `m` until one of the following occurs:

- It executes `pthread_mutex_unlock()` with `m` as the `mutex` argument
- It blocks in a call to `pthread_cond_clockwait()`, `pthread_cond_timedwait()`, or `pthread_cond_wait()` with `m` as the `mutex` argument.

The implementation shall behave as if at all times there is at most one owner of any mutex.

A thread that becomes the owner of a mutex is said to have ``acquired” the mutex and the mutex is said to have become “locked”; when a thread gives up ownership of a mutex it is said to have ``released” the mutex and the mutex is said to have become “unlocked”.

A problem can occur if a process terminates while one of its threads holds a mutex lock. Depending on the mutex type, it might be possible for another thread to unlock the mutex and recover the state of the mutex. However, it is difficult to perform this recovery reliably.

Robust mutexes provide a means to enable the implementation to notify other threads in the event of a process terminating while one of its threads holds a mutex lock. The next thread that acquires the mutex is notified about the termination by the return value [EOWNERDEAD] from the locking function. The notified thread can then attempt to recover the state protected by the mutex, and if successful mark the state protected by the mutex as consistent by a call to `pthread_mutex_consistent()`. If the notified thread is unable to recover the state, it can declare the state as not recoverable by a call to `pthread_mutex_unlock()` without a prior call to `pthread_mutex_consistent()`.

Whether or not the state protected by a mutex can be recovered is dependent solely on the application using robust mutexes. The robust mutex support provided in the implementation provides notification only that a mutex owner has terminated while holding a lock, or that the state of the mutex is not recoverable.
Cancellation points shall occur when a thread is executing the following functions:

- accept()
- accept4()
- aio_suspend()
- clock_nanosleep()
- close()
- connect()
- creat()
- fcntl()†
- fdatasync()
- fsync()
- lockf()††
- mq_receive()
- mq_send()
- mq_timedreceive()
- mq_timedsend()
- msgrcv()
- msgsnd()
- msync()
- nanosleep()
- open()
- openat()
- pause()
- poll()
- ppoll()
- pread()
- pselect()
- pthread_cond_clockwait()
- pthread_cond_timedwait()
- pthread_cond_wait()
- pthread_join()
- pthread_testcancel()
- pwrite()
- read()
- readv()
- recv()
- recvfrom()
- recvmsg()
- select()
- send()
- sendmsg()
- sendto()
- sigsuspend()
- sigtimedwait()
- sigwait()
- sigwaitinfo()
- sleep()
- tcdrain()
- wait()
- waitid()
- waitpid()
- wait()
- waitid()
- waitpid()
- write()
- writev()
- fchownat()
- fsetpos()
- fstat()
- fstatat()
- ftell()
- fgetwc()
- fgetws()
- fgetwc()
- fgetws()
- fgetwc()
- fgetwc()
- fsetpos()
- fsetpos()
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In addition, a cancellation point may occur when a thread is executing any function that this standard does not require to be thread-safe but the implementation documents as being thread-safe. If a thread is cancelled while executing a non-thread-safe function, the behavior is undefined.

An implementation shall not introduce cancellation points into any other functions specified in this volume of POSIX.1-202x.

The side-effects of acting upon a cancellation request while suspended during a call of a function are the same as the side-effects that may be seen in a single-threaded program when a call to a function is interrupted by a signal and the given function returns [EINTR]. Any such side-effects occur before any cancellation cleanup handlers are called. For functions that are explicitly required not to return when interrupted (for example, `pclose()`), if a thread is canceled while executing the function, the behavior is undefined.

Whenever a thread has cancelability enabled and a cancellation request has been made with that thread as the target, and the thread then calls any function that is a cancellation point (such as `pthread_testcancel()` or `read()`), the cancellation request shall be acted upon before the function returns. If a thread has cancelability enabled and a cancellation request is made with the thread
### Defined Types

All of the data types used by various functions are defined by the implementation. The following table describes some of these types. Other types referenced in the description of a function, not mentioned here, can be found in the appropriate header for that function.

<table>
<thead>
<tr>
<th>Defined Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cc_t</td>
<td>Type used for terminal special characters.</td>
</tr>
<tr>
<td>clock_t</td>
<td>Integer or real-floating type used for processor times, as defined in the ISO C standard.</td>
</tr>
<tr>
<td>clockid_t</td>
<td>Used for clock ID type in some timer functions.</td>
</tr>
<tr>
<td>dev_t</td>
<td>Integer type used for device numbers.</td>
</tr>
<tr>
<td>DIR</td>
<td>Type representing a directory stream.</td>
</tr>
<tr>
<td>div_t</td>
<td>Structure type returned by the <code>div()</code> function.</td>
</tr>
<tr>
<td>FILE</td>
<td>Structure containing information about a file.</td>
</tr>
<tr>
<td>glob_t</td>
<td>Structure type used in pathname pattern matching.</td>
</tr>
<tr>
<td>fpos_t</td>
<td>Type containing all information needed to specify uniquely every position within a file.</td>
</tr>
<tr>
<td>gid_t</td>
<td>Integer type used for group IDs.</td>
</tr>
<tr>
<td>iconv_t</td>
<td>Type used for conversion descriptors.</td>
</tr>
<tr>
<td>id_t</td>
<td>Integer type used as a general identifier; can be used to contain at least the largest of a <code>pid_t</code>, <code>uid_t</code>, or <code>gid_t</code>.</td>
</tr>
<tr>
<td>ino_t</td>
<td>Unsigned integer type used for file serial numbers.</td>
</tr>
<tr>
<td>key_t</td>
<td>Arithmetic type used for XSI interprocess communication.</td>
</tr>
<tr>
<td>ldiv_t</td>
<td>Structure type returned by the <code>ldiv()</code> function.</td>
</tr>
<tr>
<td>mode_t</td>
<td>Integer type used for file attributes.</td>
</tr>
<tr>
<td>mqd_t</td>
<td>Used for message queue descriptors.</td>
</tr>
<tr>
<td>nfds_t</td>
<td>Integer type used for the number of file descriptors.</td>
</tr>
<tr>
<td>nlink_t</td>
<td>Integer type used for link counts.</td>
</tr>
<tr>
<td>off_t</td>
<td>Signed integer type used for file sizes.</td>
</tr>
<tr>
<td>pid_t</td>
<td>Signed integer type used for process and process group IDs.</td>
</tr>
<tr>
<td>pthread_attr_t</td>
<td>Used to identify a thread attribute object.</td>
</tr>
<tr>
<td>pthread_cond_t</td>
<td>Used for condition variables.</td>
</tr>
<tr>
<td>pthread_condattr_t</td>
<td>Used to identify a condition attribute object.</td>
</tr>
<tr>
<td>pthread_key_t</td>
<td>Used for thread-specific data keys.</td>
</tr>
<tr>
<td>pthread_mutex_t</td>
<td>Used for mutexes.</td>
</tr>
<tr>
<td>pthread_mutexattr_t</td>
<td>Used to identify a mutex attribute object.</td>
</tr>
<tr>
<td>pthread_once_t</td>
<td>Used for dynamic package initialization.</td>
</tr>
<tr>
<td>pthread_rwlock_t</td>
<td>Used for read-write locks.</td>
</tr>
<tr>
<td>pthread_rwlockattr_t</td>
<td>Used for read-write lock attributes.</td>
</tr>
<tr>
<td>pthread_t</td>
<td>Used to identify a thread.</td>
</tr>
<tr>
<td>ptdiff_t</td>
<td>Signed integer type of the result of subtracting two pointers.</td>
</tr>
<tr>
<td>reflen_t</td>
<td>Unsigned integer type used for directory entry lengths.</td>
</tr>
<tr>
<td>regex_t</td>
<td>Structure type used in regular expression matching.</td>
</tr>
<tr>
<td>regmatch_t</td>
<td>Structure type used in regular expression matching.</td>
</tr>
<tr>
<td>rlim_t</td>
<td>Unsigned integer type used for limit values, to which objects of type <code>int</code> and <code>off_t</code> can be cast without loss of value.</td>
</tr>
<tr>
<td>sem_t</td>
<td>Type used in performing semaphore operations.</td>
</tr>
<tr>
<td>sig_atomic_t</td>
<td>Possibly volatile-qualified integer type of an object that can be accessed as an atomic entity, even in the presence of asynchronous interrupts.</td>
</tr>
<tr>
<td>sigset_t</td>
<td>Integer or structure type of an object used to represent sets</td>
</tr>
</tbody>
</table>
NAME
bind — bind a name to a socket

SYNOPSIS
#include <sys/socket.h>

int bind(int socket, const struct sockaddr *address,
         socklen_t address_len);

DESCRIPTION
The bind() function shall assign a local socket address address to a socket identified by descriptor socket that has no local socket address assigned. Sockets created with the socket() function are initially unnamed; they are identified only by their address family.

The bind() function takes the following arguments:

socket Specifies the file descriptor of the socket to be bound.
address Points to a sockaddr structure containing the address to be bound to the socket. The length and format of the address depend on the address family of the socket.
address_len Specifies the length of the sockaddr structure pointed to by the address argument.

The socket specified by socket may require the process to have appropriate privileges to use the bind() function.

If the address family of the socket is AF_UNIX and the pathname in address names a symbolic link, bind() shall fail and set errno to [EADDRINUSE].

If the socket address cannot be assigned immediately and O_NONBLOCK is set for the file descriptor for the socket, bind() shall fail and set errno to [EINPROGRESS], but the assignment request shall not be aborted, and the assignment shall be completed asynchronously. Subsequent calls to bind() for the same socket, before the assignment is completed, shall fail and set errno to [EALREADY].

When the assignment has been performed asynchronously, pselect(), select(), poll(), and ppoll() shall indicate that the file descriptor for the socket is ready for reading and writing.

RETURN VALUE
Upon successful completion, bind() shall return 0; otherwise, −1 shall be returned and errno set to indicate the error.

ERRORS
The bind() function shall fail if:

[EADDRINUSE] The specified address is already in use.
[EADDRNOTAVAIL] The specified address is not available from the local machine.
[EAFNOSUPPORT] The specified address is not a valid address for the address family of the specified socket.
[EALREADY] An assignment request is already in progress for the specified socket.
[EBADF] The socket argument is not a valid file descriptor.
connect( )

NAME
connect — connect a socket

SYNOPSIS
#include <sys/socket.h>
int connect(int socket, const struct sockaddr *address,
socklen_t address_len);

DESCRIPTION
The connect() function shall attempt to make a connection on a connection-mode socket or to set
or reset the peer address of a connectionless-mode socket. The function takes the following
arguments:

socket Specifies the file descriptor associated with the socket.
address Points to a sockaddr structure containing the peer address. The length and
format of the address depend on the address family of the socket.
address_len Specifies the length of the sockaddr structure pointed to by the address
argument.

If the socket has not already been bound to a local address, connect() shall bind it to an address
which, unless the socket’s address family is AF_UNIX, is an unused local address.

If the initiating socket is not connection-mode, then connect() shall set the socket’s peer address,
and no connection is made. For SOCK_DGRAM sockets, the peer address identifies where all
datagrams are sent on subsequent send() functions, and limits the remote sender for subsequent
recv() functions. If the sa_family member of address is AF_UNSPEC, the socket’s peer address
shall be reset. Note that despite no connection being made, the term “connected” is used to
derive a connectionless-mode socket for which a peer address has been set.

If the initiating socket is connection-mode, then connect() shall attempt to establish a connection
to the address specified by the address argument. If the connection cannot be established
immediately and O_NONBLOCK is not set for the file descriptor for the socket, connect() shall
block for up to an unspecified timeout interval until the connection is established. If the timeout
interval expires before the connection is established, connect() shall fail and the connection
attempt shall be aborted. If connect() is interrupted by a signal that is caught while blocked
waiting to establish a connection, connect() shall fail and set errno to [EINTR], but the connection
request shall not be aborted, and the connection shall be established asynchronously.

If the connection cannot be established immediately and O_NONBLOCK is set for the file
descriptor for the socket, connect() shall fail and set errno to [EINPROGRESS], but the connection
request shall not be aborted, and the connection shall be established asynchronously. Subsequent
calls to connect() for the same socket, before the connection is established, shall fail and set errno
to [EALREADY].

When the connection has been established asynchronously, pselect(), select(), poll(), and ppoll() shall
indicate that the file descriptor for the socket is ready for writing.

The socket in use may require the process to have appropriate privileges to use the connect() function.

RETURN VALUE
Upon successful completion, connect() shall return 0; otherwise, −1 shall be returned and errno
set to indicate the error.
NAME

dladdr — get information relating to an address

SYNOPSIS

```c
#include <dlfcn.h>

int dladdr(const void *restrict addr, Dl_info_t *restrict dlip);
```

DESCRIPTION

The `dladdr()` function shall determine whether the address specified by `addr` is located within the address range occupied by a mapped object. The mapped objects examined shall include any executable object files that have previously been loaded by a call to `dlopen()` and for which `dlclose()` has not subsequently been called, and any shared library files that were loaded as dependencies of the executable file from which the current process image was loaded; they may also include any executable object files that have previously been loaded by a call to `dlopen()` and for which `dlclose()` has subsequently been called, the executable file from which the current process image was loaded, and implementation-defined additional mapped objects (for example, all regular files mapped using `mmap()` might be included). If the specified address is within the mapped address range of one of these mapped objects and the object contains a symbol table, the symbol table shall be searched for a symbol (a function identifier or a data object identifier) that has the largest address less than or equal to the specified address.

If the address specified by `addr` is within the mapped address range of one of the examined mapped objects, the structure pointed to by `dlip` shall be populated as follows:

- The value of the `dli_fname` member shall be set to point to the pathname of the mapped object. (This might no longer resolve to the file that was mapped, for example if it was a link that has subsequently been removed or renamed.)
- The value of the `dli_fbase` member shall be set to the base of the address range occupied by the mapped object.
- The value of the `dli_sname` member shall be set to point to the name of the symbol that has the largest address less than or equal to the specified address, or to a null pointer if no such symbol was found.
- If `dli_sname` is set to a null pointer, the value of the `dli_saddr` member shall also be set to a null pointer. Otherwise, if `dli_sname` names a function identifier, `dli_saddr` shall be set to the address of the function converted from type pointer to function to type pointer to `void`; otherwise, `dli_saddr` shall be set to the address of the data object named by `dli_sname` converted from a pointer to the type of the data object to a pointer to `void`.

RETURN VALUE

Upon successful completion, a non-zero value shall be returned. If the specified address is not located within the address range occupied by an examined mapped object, or if an error occurs, zero shall be returned. More detailed diagnostic information shall be available through `dlerror()`.

ERRORS

No errors are defined.
EXAMPLES
None.

APPLICATION USAGE
The DL_info_t members may point to addresses within the mapped object. These pointers can become invalid if the object is unmapped (for example, loaded executable objects may be unloaded by dlclose()).

If dli_sname names a function identifier, the value of dli_saddr can be converted back to type pointer to function using a cast in the manner shown in the dlsym() EXAMPLES section. Note that this conversion is not defined by the ISO C standard. This standard requires this conversion to work correctly on conforming implementations.

RATIONALE
None.

FUTURE DIRECTIONS
None.

SEE ALSO
dlclose(), dlerror(), dlopen(), dlsym()
XBD <dlfcn.h>

CHANGE HISTORY
First released in Issue 8.
drand48()

assert(xsubi[1] == 10728);
assert(xsubi[2] == 27921);
assert(nrand48(xsubi) == 754104482);
assert(xsubi[0] == 6828);
assert(xsubi[1] == 28997);
assert(xsubi[2] == 23013);
assert(nrand48(xsubi) == 609453945);
assert(xsubi[0] == 58183);
assert(xsubi[1] == 3826);
assert(xsubi[2] == 18599);
assert(nrand48(xsubi) == 1878644360);
assert(xsubi[0] == 36678);
assert(xsubi[1] == 44304);
assert(xsubi[2] == 57331);
assert(nrand48(xsubi) == 2114923686);
assert(xsubi[0] == 58585);
assert(xsubi[1] == 22861);
assert(xsubi[2] == 64542);

APPLICATION USAGE

These functions should be avoided whenever non-trivial requirements (including safety) have to be fulfilled, unless seeded using getentropy().

RATIONALE

None.

FUTURE DIRECTIONS

None.

SEE ALSO

gentropy(), initstate(), rand()

XBD <stdlib.h>

CHANGE HISTORY

First released in Issue 1. Derived from Issue 1 of the SVID.

Issue 5

A note indicating that the drand48(), lrand48(), and mrand48() functions need not be reentrant is added to the DESCRIPTION.

Issue 6

The normative text is updated to avoid use of the term "must" for application requirements.

Issue 7

Austin Group Interpretation 1003.1-2001 #156 is applied.


Issue 8

Austin Group Defect 1107 is applied, clarifying how the return value is calculated from X_i for each function. +

Austin Group Defect 1134 is applied, adding getentropy(). |
possible for the system to conform to the intent of this volume of POSIX.1-202x.

The [EAGAIN] error exists to warn applications that such a condition might occur. Whether it occurs or not is not in any practical sense under the control of the application because the condition is usually a consequence of the user’s use of the system, not of the application’s code. Thus, no application can or should rely upon its occurrence under any circumstances, nor should the exact semantics of what concept of “user” is used be of concern to the application developer. Validation writers should be cognizant of this limitation.

There are two reasons why POSIX programmers call `fork()`. One reason is to create a new thread of control within the same program (which was originally only possible in POSIX by creating a new process); the other is to create a new process running a different program. In the latter case, the call to `fork()` is soon followed by a call to one of the `exec` functions.

The general problem with making `fork()` work in a multi-threaded world is what to do with all of the threads. There are two alternatives. One is to copy all of the threads into the new process. This causes the programmer or implementation to deal with threads that are suspended on system calls or that might be about to execute system calls that should not be executed in the new process. The other alternative is to copy only the thread that calls `fork()`. This creates the difficulty that the state of process-local resources is usually held in process memory. If a thread that is not calling `fork()` holds a resource, that resource is never released in the child process because the thread whose job it is to release the resource does not exist in the child process.

When a programmer is writing a multi-threaded program, the first described use of `fork()`, creating new threads in the same program, is provided by the `pthread_create()` function. The `fork()` function is thus used only to run new programs, and the effects of calling functions that require certain resources between the call to `fork()` and the call to an `exec` function are undefined.

The addition of the `forkall()` function to the standard was considered and rejected. The `forkall()` function lets all the threads in the parent be duplicated in the child. This essentially duplicates the state of the parent in the child. This allows threads in the child to continue processing and allows locks and the state to be preserved without explicit `pthread_atfork()` code. The calling process has to ensure that the threads processing state that is shared between the parent and child (that is, file descriptors or MAP_SHARED memory) behaves properly after `forkall()`. For example, if a thread is reading a file descriptor in the parent when `forkall()` is called, then two threads (one in the parent and one in the child) are reading the file descriptor after the `forkall()`. If this is not desired behavior, the parent process has to synchronize with such threads before calling `forkall()`.

When `forkall()` is called, threads, other than the calling thread, that are in functions that can return with an [EINTR] error may have those functions return [EINTR] if the implementation cannot ensure that the function behaves correctly in the parent and child. In particular, `pthread_cond_clockwait()`, `pthread_cond_timedwait()`, and `pthread_cond_wait()` need to return in order to ensure that the condition has not changed. These functions can be awakened by a spurious condition wakeup rather than returning [EINTR].

**FUTURE DIRECTIONS**

None.

**SEE ALSO**

`alarm()`, `exec`, `fcntl()`, `pthread_atfork()`, `semop()`, `signal()`, `times()`

XBD Section 4.13 (on page 91), `<sys/types.h>`, `<unistd.h>`
NAME
   free — free allocated memory

SYNOPSIS
   #include <stdlib.h>
   void free(void *ptr);

DESCRIPTION
   The functionality described on this reference page is aligned with the ISO C standard. Any
   conflict between the requirements described here and the ISO C standard is unintentional. This
   volume of POSIX.1-202x defers to the ISO C standard.
   The free() function shall cause the space pointed to by ptr to be deallocated; that is, made
   available for further allocation. If ptr is a null pointer, no action shall occur. Otherwise, if the
   argument does not match a pointer earlier returned by a function in POSIX.1-202x that allocates
   memory as if by malloc(), or if the space has been deallocated by a call to free(), realloc(), or |
   reallocarray(), the behavior is undefined.
   Any use of a pointer that refers to freed space results in undefined behavior.
   The free() function shall not modify errno if ptr is a null pointer or a pointer previously returned
   as if by malloc() and not yet deallocated.

RETURN VALUE
   The free() function shall not return a value.

ERRORS
   No errors are defined.

EXAMPLES
   None.

APPLICATION USAGE
   There is now no requirement for the implementation to support the inclusion of <malloc.h>.
   Because the free() function does not modify errno for valid pointers, it is safe to use it in cleanup
   code without corrupting earlier errors, such as in this example code:

   // buf was obtained by malloc(buflen)
   ret = write(fd, buf, buflen);
   if (ret < 0) {
      free(buf);
      return ret;
   }

   However, earlier versions of this standard did not require this, and the same example had to be
   written as:

   // buf was obtained by malloc(buflen)
   ret = write(fd, buf, buflen);
   if (ret < 0) {
      int save = errno;
      free(buf);
      errno = save;
      return ret;
   }
NAME
getentropy — fill a buffer with random bytes

SYNOPSIS
#include <unistd.h>
int getentropy(void *buffer, size_t length);

DESCRIPTION
The getentropy() function shall write length bytes of data starting at the location pointed to by
buffer. The output shall be unpredictable high quality random data, generated by a
cryptographically secure pseudo-random number generator. The maximum permitted value for
the length argument is given by the [GETENTROPY_MAX] symbolic constant defined in
<limits.h>.
A successful call to getentropy() shall always provide the requested number of bytes of entropy.

RETURN VALUE
Upon successful completion, getentropy() shall return 0; otherwise, −1 shall be returned and
errno set to indicate the error.

ERRORS
The getentropy() function shall fail if:
[EINVAL] The value of length is greater than [GETENTROPY_MAX].
The getentropy() function may fail if:
[ENOSYS] The system does not provide the necessary source of entropy.

EXAMPLES
None.

APPLICATION USAGE
The intended use of this function is to create a seed for other pseudo-random number
generators.

RATIONALE
The getentropy() function is not a cancellation point. (See Section 2.9.5.2 (on page 504).)

FUTURE DIRECTIONS
None.

SEE ALSO
drand48(), initstate(), rand()
XBD <limits.h>, <unistd.h>

CHANGE HISTORY
First released in Issue 8.
**NAME**

getlocalename_l — get a locale name from a locale object

**SYNOPSIS**

```c
#include <locale.h>

const char *getlocalename_l(int category, locale_t locobj);
```

**DESCRIPTION**

The `getlocalename_l()` function shall return the locale name for the given locale category of the locale object `locobj`, or of the global locale if `locobj` is the special locale object LC_GLOBAL_LOCALE.

The `category` argument specifies the locale category to be queried. If the value is LC_ALL or is not a supported locale category value (see `setlocale()`), `getlocalename_l()` shall fail.

The behavior is undefined if the `locobj` argument is neither the special locale object LC_GLOBAL_LOCALE nor a valid locale object handle.

**RETURN VALUE**

Upon successful completion, `getlocalename_l()` shall return a pointer to a string containing the locale name; otherwise, a null pointer shall be returned.

If `locobj` is LC_GLOBAL_LOCALE, the returned string pointer might be invalidated or the string content might be overwritten by a subsequent call in the same thread to `getlocalename_l()` with LC_GLOBAL_LOCALE; the returned string pointer might also be invalidated if the calling thread is terminated. Otherwise, the returned string pointer and content shall remain valid until the locale object `locobj` is used in a call to `freelocale()` or as the base argument in a successful call to `newlocale()`.

**ERRORS**

No errors are defined.

**EXAMPLES**

Determining the locale name for a category of the current locale

The following example shows how to obtain the locale name for the LC_NUMERIC category of the current thread-local locale, or of the global locale if no thread-local locale is in use.

```c
#include <locale.h>
...
const char *name;
locale_t loc = uselocale(NULL);
name = getlocalename_l(LC_NUMERIC, loc);
```

**APPLICATION USAGE**

None.

**RATIONALE**

Historical versions of `getlocalename_l()` did not handle the special locale object LC_GLOBAL_LOCALE, requiring that applications used `setlocale(category, NULL)` to query the global locale if `uselocale(NULL)` returned LC_GLOBAL_LOCALE. However, since `setlocale()` is not required to be thread-safe (even when the only concurrent calls are ones that query the locale), this method was problematic for multi-threaded processes. This standard requires that `getlocalename_l(category, LC_GLOBAL_LOCALE)` queries the global locale in a thread-safe manner, for example by returning a pointer to a thread-local internal buffer instead of a process-wide internal buffer.
FUTURE DIRECTIONS
None.

SEE ALSO
freelocale(), newlocale(), setlocale(), uselocale()

CHANGE HISTORY
First released in Issue 8.
ERRORS
No errors are defined.

EXAMPLES
None.

APPLICATION USAGE
After initialization, a state array can be restarted at a different point in one of two ways:

1. The `initstate()` function can be used, with the desired seed, state array, and size of the array.

2. The `setstate()` function, with the desired state, can be used, followed by `srandom()` with the desired seed. The advantage of using both of these functions is that the size of the state array does not have to be saved once it is initialized.

Although some implementations of `random()` have written messages to standard error, such implementations do not conform to POSIX.1-202x.

Issue 5 restored the historical behavior of this function.

Threaded applications should use `erand48()`, `nrand48()`, or `jrand48()` instead of `random()` when an independent random number sequence in multiple threads is required.

These functions should be avoided whenever non-trivial requirements (including safety) have to be fulfilled, unless seeded using `getentropy()`.

RATIONALE
None.

FUTURE DIRECTIONS
None.

SEE ALSO
None.

`drand48()`, `getentropy()`, `rand()`

XBD `<stdlib.h>`

CHANGE HISTORY
First released in Issue 4, Version 2.

Issue 5
Moved from X/OPEN UNIX extension to BASE.

In the DESCRIPTION, the phrase “values smaller than 8” is replaced with “values greater than or equal to 8, or less than 32”, “size<8” is replaced with “8<size<32”, and a new first paragraph is added to the RETURN VALUE section. A note is added to the APPLICATION USAGE indicating that these changes restore the historical behavior of the function.

Issue 6
In the DESCRIPTION, duplicate text “For values greater than or equal to 8 . . . ” is removed.

IEEE Std 1003.1-2001/Cor 1-2002, item XSH/TC1/D6/30 is applied, removing `rand_r()` from the list of suggested functions in the APPLICATION USAGE section.

Issue 7
The type of the first argument to `setstate()` is changed from `const char *` to `char *`.

### NAME

`memmem()` — find a byte subsequence in a byte sequence

### SYNOPSIS

```c
#include <string.h>

void *memmem(const void *haystack, size_t haystacklen,
              const void *needle, size_t needlelen);
```

### DESCRIPTION

The `memmem()` function shall locate the first occurrence of byte sequence `needle` of length `needlelen` in byte sequence `haystack` of length `haystacklen`.

### RETURN VALUE

Upon successful completion, `memmem()` shall return a pointer to the first byte of the located byte sequence in `haystack`, or a null pointer if the byte sequence is not found.

If `needlelen` is zero, the function shall return `haystack`.

If `haystacklen` is less than `needlelen`, the function shall return a null pointer.

### ERRORS

No errors are defined.

### EXAMPLES

None.

### APPLICATION USAGE

None.

### RATIONALE

This function is similar to `strstr()`, except that NUL bytes may be included in either `needle` or `haystack`.

### FUTURE DIRECTIONS

None.

### SEE ALSO

`memchr()`, `strstr()`

XBD `<string.h>`

### CHANGE HISTORY

First released in Issue 8.
NAME

poll, ppoll — input/output multiplexing

SYNOPSIS

```c
#include <poll.h>

int poll(struct pollfd fds[], nfds_t nfds, int timeout);
int ppoll(struct pollfd fds[], nfds_t nfds,
          const struct timespec *restrict timeout,
          const sigset_t *restrict sigmask);
```

DESCRIPTION

The `ppoll()` function provides applications with a mechanism for multiplexing input/output over a set of file descriptors. For each member of the array pointed to by `fds`, `ppoll()` shall examine the given file descriptor for the event(s) specified in `events`. The number of `pollfd` structures in the `fds` array is specified by `nfds`. The `ppoll()` function shall identify those file descriptors on which an application can read or write data, or on which certain events have occurred.

The `poll()` function shall be equivalent to the `ppoll()` function, except as follows:

- For the `poll()` function, the timeout period is given in milliseconds in an argument of type `int`, whereas for the `ppoll()` function the timeout period is given in seconds and nanoseconds via an argument of type pointer to `struct timespec`. A timeout of −1 for `poll()` shall be equivalent to passing a null pointer for the `timeout` for `ppoll()`.

- The `poll()` function has no `sigmask` argument; it shall behave as `ppoll()` does when `sigmask` is a null pointer.

The `fds` argument specifies the file descriptors to be examined and the events of interest for each file descriptor. It is a pointer to an array with one member for each open file descriptor of interest. The array’s members are `pollfd` structures within which `fd` specifies an open file descriptor and `events` and `revents` are bitmasks constructed by OR’ing a combination of the following event flags:

- `POLLIN` Data other than high-priority data may be read without blocking.
- `POLLRDNORM` Normal data may be read without blocking.
- `POLLRDBAND` Priority data may be read without blocking.
- `POLLPRI` High-priority data may be read without blocking.
- `POLLOUT` Normal data may be written without blocking.
- `POLLWRNORM` Equivalent to `POLLOUT`.
- `POLLWRBAND` Priority data may be written.
- `POLLERR` An error has occurred on the device or stream. This flag is only valid in the `revents` bitmask; it shall be ignored in the `events` member.
- `POLLHUP` A device has been disconnected, or a pipe or FIFO has been closed by the last process that had it open for writing. Once set, the hangup state of a FIFO shall persist until some process opens the FIFO for writing or until all read-only file descriptors for the FIFO are closed. This event and `POLLOUT` are mutually-exclusive; a stream can never be writable if a hangup has occurred. However, this event and `POLLIN`, `POLLRDNORM`, `POLLRDBAND`, or `POLLPRI` are not mutually-exclusive. This flag is only valid in the `revents` bitmask; it shall be ignored in the `events` member.
poll()  System Interfaces

POLLNVAL  The specified fd value is invalid. This flag is only valid in the revents member; it shall be ignored in the events member.

The significance and semantics of normal, priority, and high-priority data are file and device-specific.

If the value of fd is less than 0, events shall be ignored, and revents shall be set to 0 in that entry on return from poll() or ppoll().

In each pollfd structure, poll() or ppoll() shall clear the revents member, except that where the application requested a report on a condition by setting one of the bits of events listed above, poll() or ppoll() shall set the corresponding bit in revents if the requested condition is true. In addition, poll() or ppoll() shall set the POLLHUP, POLLERR, and POLLNVAL flag in revents if the condition is true, even if the application did not set the corresponding bit in events.

The timeout argument controls how long the poll() or ppoll() function shall wait before timing out. If the timeout argument is positive for poll() or not a null pointer for ppoll(), it specifies a maximum interval to wait for the poll to complete. If the specified time interval expires without any of the defined events having occurred, the function shall return. If the timeout argument is −1 for poll() or a null pointer for ppoll(), then the call shall block indefinitely until at least one descriptor meets the specified criteria or until the call is interrupted. To effect a poll, the application shall ensure that the timeout argument for poll() is 0, or for ppoll() is not a null pointer and points to a zero-valued timespec structure.

Implementations may place limitations on the maximum timeout interval supported. All implementations shall support a maximum timeout interval of at least 31 days for ppoll(). If the timeout argument specifies a timeout interval greater than the implementation-defined maximum value, the maximum value shall be used as the actual timeout value. Implementations may also place limitations on the granularity of timeout intervals. If the requested timeout interval requires a finer granularity than the implementation supports, the actual timeout interval shall be rounded up to the next supported value.

The poll() and ppoll() functions shall not be affected by the O_NONBLOCK flag.

The poll() and ppoll() functions shall support regular files, terminal and pseudo-terminal devices, FIFOs, pipes, and sockets. The behavior of poll() and ppoll() on elements of fds that refer to other types of file is unspecified.

Regular files shall always poll TRUE for reading and writing.

A file descriptor for a socket that is listening for connections shall indicate that it is ready for reading, once connections are available. A file descriptor for a socket that is connecting asynchronously shall indicate that it is ready for writing, once a connection has been established.

Provided the application does not perform any action that results in unspecified or undefined behavior, the value of the fd and events members of each element of fds shall not be modified by poll() or ppoll().

If sigmask is not a null pointer, the ppoll() function shall replace the signal mask of the caller by the set of signals pointed to by sigmask before examining the descriptors, and shall restore the signal mask of the calling thread before returning. If a signal is unmasked as a result of the signal mask being altered by ppoll(), and a signal-catching function is called for that signal during the execution of the ppoll() function, and SA_RESTART is clear for the interrupting signal, then

- If none of the defined events have occurred on any selected file descriptor, ppoll() shall immediately fail with the [EINTR] error after the signal-catching function returns.
If one or more of the defined events have occurred, it is unspecified whether \texttt{ppoll()} behaves the same as if none of the events had occurred (failing with \texttt{EINTR} as above) or behaves the same as if it was not interrupted (returning the total number of \texttt{pollfd} structures that have selected events).

If a thread is canceled during a \texttt{ppoll()} call, it is unspecified whether the signal mask in effect when executing the registered cleanup functions is the original signal mask or the signal mask installed as part of the \texttt{ppoll()} call.

**RETURN VALUE**

Upon successful completion, a non-negative value shall be returned. A positive value shall indicate the total number of \texttt{pollfd} structures that have selected events (that is, those for which the \texttt{revents} member is non-zero). A value of 0 shall indicate that the call timed out and no file descriptors have been selected. Upon failure, −1 shall be returned and \texttt{errno} set to indicate the error.

**ERRORS**

The \texttt{poll()} and \texttt{ppoll()} functions shall fail if:

- [EAGAIN] The allocation of internal data structures failed but a subsequent request may succeed.
- [EINTR] A signal was caught during \texttt{poll()} or \texttt{ppoll()}.
- [EINVAL] The \texttt{nfds} argument is greater than \{OPEN\_MAX\}.

The \texttt{ppoll()} function shall fail if:

- [EINVAL] An invalid timeout interval was specified.

**EXAMPLES**

None.

**APPLICATION USAGE**

Other than the difference in the precision of the requested timeout, the following \texttt{ppoll()} call:

\begin{verbatim}
ready = ppoll(&fds, nfds, tmo_p, &sigmask);
\end{verbatim}

is equivalent to atomically executing the following calls:

\begin{verbatim}
signet_t origmask;
int timeout;
timeout = (tmo_p == NULL) ? -1 :
    (tmo_p->tv_sec * 1000 + tmo_p->tv_nsec / 1000000);
pthread_sigmask(SIG_SETMASK, &sigmask, &origmask);
ready = poll(&fds, nfds, timeout);
pthread_sigmask(SIG_SETMASK, &origmask, NULL);
\end{verbatim}

**RATIONALE**

The POLLHUP event does not occur for FIFOs just because the FIFO is not open for writing. It only occurs when the FIFO is closed by the last writer and persists until some process opens the FIFO for writing or until all read-only file descriptors for the FIFO are closed.

Code which wants to avoid the ambiguity of the signal mask for thread cancellation handlers can install an additional cancellation handler which resets the signal mask to the expected value:

\begin{verbatim}
void cleanup(void *arg)
{
    sigset_t *ss = (sigset_t *) arg;
\end{verbatim}
poll()

System Interfaces

```c
int call_ppoll(struct pollfd fds[], nfds_t nfds,
   const struct timespec *restrict timeout,
   const sigset_t *restrict sigmask)
{
    sigset_t oldmask;
    int result;
    pthread_sigmask(SIG_SETMASK, NULL, &oldmask);
    pthread_cleanup_push(cleanup, &oldmask);
    result = ppoll(fds, nfds, timeout, sigmask);
    pthread_cleanup_pop(0);
    return result;
}
```

FUTURE DIRECTIONS

None.

SEE ALSO

pselect(), read(), write()

XBD <poll.h>

CHANGE HISTORY

First released in Issue 4, Version 2.

Issue 5

Moved from X/OPEN UNIX extension to BASE.

The description of POLLWRBAND is updated.

Issue 6

Text referring to sockets is added to the DESCRIPTION.

Functionality relating to the XSI STREAMS Option Group is marked.

The Open Group Corrigendum U055/3 is applied, updating the DESCRIPTION of POLLWRBAND.

IEEE Std 1003.1-2001/Cor 2-2004, item XSH/TC2/D6/66 is applied, correcting the spacing in the EXAMPLES section.

Issue 7

Austin Group Interpretation 1003.1-2001 #209 is applied, clarifying the POLLHUP event.

The poll() function is moved from the XSI option to the Base.

Functionality relating to the XSI STREAMS option is marked obsolescent.


Issue 8

Austin Group Defect 1263 is applied, adding ppoll().

Austin Group Defect 1330 is applied, removing obsolescent interfaces.
NAME

posix_getdents — read directory entries

SYNOPSIS

#include <dirent.h>

ssize_t posix_getdents(int fildes, void *buf, size_t nbyte, int flags);

DESCRIPTION

The posix_getdents() function shall attempt to read directory entries from the directory associated
with the open file descriptor fildes and shall place information about the directory entries and the
files they refer to in posix_dent structures in the buffer pointed to by buf, up to a maximum of
nbyte bytes. The number of posix_dent structures populated in buf may be fewer than the
number that will fit in nbyte bytes, but shall be at least one if nbyte is greater than the size of the
posix_dent structure plus (NAME_MAX) and fildes is not currently at end-of-file.

The application shall ensure that buf is aligned suitably to point to a posix_dent structure. The
alignment needed shall not be more restrictive than the alignment provided by malloc(). Strictly
conforming applications shall ensure that the value of flags is zero; other applications can set it to
a value constructed by a bitwise-inclusive OR of implementation-defined bitwise-distinct flag
values.

Each posix_dent structure returned in buf shall be located at an address that satisfies the
implementation’s alignment requirements for the posix_dent structure and shall be populated
as follows:

- The value of the d_ino member shall be set to the file serial number of the file named by the
d_name member.
- The value of the d_reclen member shall be set to the number of bytes occupied by this entry
in buf, including any padding bytes needed before the next entry, if any. If this is the last
entry in buf, d_reclen shall include any padding bytes needed to make the address of this
entry plus d_reclen bytes satisfy the alignment requirements for the posix_dent structure.
- The value of the d_type member shall be set to indicate the file type of the named file, if the
file type can be determined without needing to use the file serial number to obtain the
file’s metadata; otherwise it may be set to DT_UNKNOWN. If the file type is determined
and it is one of the file types defined in this standard, the value of d_type shall be DT_BLK,
DT_CHR, DT_DIR, DT_FIFO, DT_LNK, DT_REG, DT_SOCK, DT_MQ, DT_SEM,
DT_SHM, or DT_TMO (see <dirent.h>). If it is determined but is not a standard file type,
the value of d_type shall not equal any of those listed here.
- The d_name member shall be a filename string, and (if not dot or dot-dot) shall contain the
same byte sequence as the last pathname component of the string used to create the
directory entry, plus the terminating NUL byte.

If the d_name member names a symbolic link, the values of the d_ino and d_type members shall
be set to the values for the symbolic link itself.

The posix_getdents() function shall start reading at the current file offset in the open file
description associated with fildes. On successful return, the file offset shall be incremented to
point to the directory entry immediately following the last entry whose information was
returned in buf, or to point to end-of-file if there are no more directory entries. On failure, the
value of the file offset is unspecified. The current file offset can be set and retrieved using lseek()
on the open file description associated with fildes. The behavior is unspecified if lseek() is used
to set the file offset to a value other than zero or a value returned by a previous call to lseek() on
the same open file description.
The `posix_getdents()` function shall not return directory entries containing empty names. If entries for dot or dot-dot exist, a sequence of calls that reads from offset zero to end-of-file shall return one entry for dot and one entry for dot-dot; otherwise, they shall not be returned.

Upon successful completion, `posix_getdents()` shall mark for update the last data access timestamp of the directory.

If `fd` is a file descriptor associated with a directory stream opened using `fdopendir()` or `opendir()`, the behavior is unspecified.

If `posix_getdents()` is called concurrently with an operation that adds, deletes, or modifies a directory entry, the results from `posix_getdents()` shall reflect either all of the effects of the concurrent operation or none of them. If a sequence of calls to `posix_getdents()` is made that reads from offset zero to end-of-file and a file is removed from or added to the directory between the first and last of those calls, whether the sequence of calls returns an entry for that file is unspecified.

**RETURN VALUE**

Upon successful completion, either a non-negative integer shall be returned indicating the number of bytes occupied by the `posix_dent` structures placed in `buf` or 0 shall be returned indicating the end of the directory was reached without any directory entries being placed in `buf`. Otherwise, −1 shall be returned and `errno` shall be set to indicate the error.

**ERRORS**

The `posix_getdents()` function shall fail if:

- **[EBADF]** The `fd` argument is not a valid file descriptor open for reading.
- **[EINVAL]** The `nbyte` argument is not large enough to contain the information to be returned about the directory entry located at the current file offset.
- **[ENOENT]** The current file offset is not located at a valid directory entry.
- **[ENOTDIR]** The `fd` argument is associated with a non-directory file.
- **[EOVERFLOW]** One of the values in a structure to be placed in `buf` cannot be represented correctly.

The `posix_getdents()` function may fail if:

- **[EIO]** A physical I/O error has occurred.
- **[ENOMEM]** Insufficient memory was available to fulfill the request.

**EXAMPLES**

This example function lists the files in a specified directory with their file serial number and file type. If the file type is not available from `posix_getdents()`, it is obtained using `fstatat()`.  

```c
#include <dirent.h>  
#include <fcntl.h>  
#include <stdio.h>  
#include <stdlib.h>  
#include <sys/stat.h>  
#include <unistd.h>  

#define ENTBUFSIZ 10240  

int list_dir(const char *dirnam)  
{
    int fd = open(dirnam, O_RDONLY | O_DIRECTORY);
    ...  
```
if (fd == -1)
    return -1;
char *buf = malloc(ENTBUFSIZ);
if (buf == NULL)
{
    close(fd);
    return -1;
}
ssize_t bytesinbuf;
for(;;)
{
    ssize_t nextent = 0;
    bytesinbuf = posix_getdents(fd, buf, ENTBUFSIZ, 0);
    if (bytesinbuf <= 0)
        break;
    do {
        const char *ftype;
        struct posix_dent *entp = (void *)&buf[nextent];
        if (entp->d_type == DT_UNKNOWN)
        {
            struct stat stbuf;
            if (fstatat(fd, entp->d_name, &stbuf,
                        AT_SYMLINK_NOFOLLOW) == -1)
                ftype = "?";
            else
                ftype = S_ISBLK(stbuf.st_mode) ? "b" :
                    S_ISCHR(stbuf.st_mode) ? "c" :
                    S_ISDIR(stbuf.st_mode) ? "d" :
                    S_ISFIFO(stbuf.st_mode) ? "p" :
                    S_ISLNK(stbuf.st_mode) ? "l" :
                    S_ISREG(stbuf.st_mode) ? "r" :
                    S_ISSOCK(stbuf.st_mode) ? "s" :
                    S_TYPEISMQ(&stbuf) ? "mq" :
                    S_TYPEISSEM(&stbuf) ? "sem" :
                    S_TYPEISSHM(&stbuf) ? "shm" :
                    #ifdef S_TYPEISTMO
                        S_TYPEISTMO(&stbuf) ? "tmo" :
                    #endif
                    "?";
        }
        else
        {
            ftype = entp->d_type == DT_BLK ? "b" :
                    entp->d_type == DT_CHR ? "c" :
                    entp->d_type == DT_DIR ? "d" :
                    entp->d_type == DT_FIFO ? "p" :
                    entp->d_type == DT_LNK ? "l" :
                    entp->d_type == DT_REG ? "r" :
                    entp->d_type == DT_SOCK ? "s" :
                    entp->d_type == DT_MQ ? "mq" :
                    "?";
        }
        nextent ++;
    } while (bytesinbuf = posix_getdents(fd, buf, ENTBUFSIZ, 0)) > 0;
entp->d_type == DT_SEM ? "sem" :
entp->d_type == DT_SHM ? "shm" :
}

if (entp->d_reclen < bytesinbuf) {
    bytesinbuf -= entp->d_reclen;
    nextent += bytesinbuf;
}

close(fd);
free(buf);
return bytesinbuf;

APPLICATION USAGE

If an array of posix_dent structures (which is only possible on implementations where d_name is
not a flexible array member) is used to provide the storage for buf in order to satisfy the
alignment requirement, it should be noted that the number of array elements used to size the
array may bear little or no relation to the number of directory entries that can be stored in it. It is
recommended that the number of elements is calculated from the desired size in bytes, for
example:

#define DESIREDSIZE 10240
struct posix_dent buf[DESIREDSIZE / sizeof(struct posix_dent) + 1];
size_t nbyte = sizeof buf;

When posix_getdents() is called with a buf that is not type char *, it is important to note that
d_reclen is a byte count and therefore any pointer arithmetic involved in calculating the start of
the next entry needs to use a char * pointer.

On implementations where directory entries in a directory take up more space than the
corresponding posix_dent structures in buf, a call to posix_getdents() may read nbyte bytes from
the directory, resulting (in most cases) in the actual number of bytes placed in buf being less than
nbyte.

One advantage of posix_getdents() is that it provides the file type of each directory entry (if
available), whereas readdir() only does so on implementations that have the file type as a non-
standard additional member of the dirent structure. Knowing the file type can greatly reduce the
number of fstatat() calls that need to be made when traversing the file hierarchy.

Whether or not a file’s type can be determined without needing to use the file serial number to
obtain the file’s metadata may vary across the different file system types supported by an
implementation. Therefore applications should not assume that if d_type contains known file
types (i.e. not DT_UNKNOWN) for entries in a given directory then it will also contain known
file types for entries in subdirectories of that directory or in its parent.

Since the d_reclen value for the last entry in buf includes padding to satisfy alignment
requirements, applications can grow the buffer and call posix_getdents() again to append to it
without needing to perform an alignment calculation.
posix_getdents( )

RATIONALE
The posix_getdents() function was derived from existing getdents() functions but the name was changed because the existing getdents() functions differed in various ways, in particular the type of the second argument (structure pointer or void *), the members of the populated structures, and the error numbers used for some conditions. The name change also provided an opportunity to add a flags argument to provide for future extensibility.

Implementations are encouraged to include support for a DT_FORCE_TYPE flag which, when that bit is set in flags, causes posix_getdents() to look up the file type if it can not be obtained from the directory entry. This will allow applications that need to know the file type of every directory entry to keep the cost of these lookups to the minimum needed to obtain the type at the file system level, without the additional overhead of making a call to fstatat() for every file (that has d_type equal to DT_UNKNOWN).

Some existing getdents() or similar functions return directory entry structures for deleted directory entries in buf, marked with a special value of one of the structure members to distinguish them from non-deleted entries. This behavior is not allowed for posix_getdents(), although the data from a deleted directory entry may be present in buf in the form of extra padding on the end of the previous entry.

FUTURE DIRECTIONS
A future version of this standard may add a DT_FORCE_TYPE flag as described in RATIONALE.

SEE ALSO
fdopendir(), fstatat(), lseek(), readdir()

XBD <dirent.h>

CHANGE HISTORY
First released in Issue 8.
System Interfaces

NAME
ppoll — input/output multiplexing

SYNOPSIS
#include <poll.h>

int ppoll(struct pollfd fds[], nfds_t nfds,
          const struct timespec *restrict timeout,
          const sigset_t *restrict sigmask);

DESCRIPTION
Refer to poll().

of the `pselect()` call.

**RETURN VALUE**

Upon successful completion, the `pselect()` and `select()` functions shall return the total number of bits set in the bit masks. Otherwise, −1 shall be returned, and `errno` shall be set to indicate the error.

`FD_CLR()`, `FD_SET()`, and `FD_ZERO()` do not return a value. `FD_ISSET()` shall return a non-zero value if the bit for the file descriptor `fd` is set in the file descriptor set pointed to by `fdset`, and 0 otherwise.

**ERRORS**

Under the following conditions, `pselect()` and `select()` shall fail and set `errno` to:

- `[EBADF]` One or more of the file descriptor sets specified a file descriptor that is not a valid open file descriptor.
- `[EINTR]` The function was interrupted by a signal.
- `[EINVAL]` An invalid timeout interval was specified.
- `[EINVAL]` The `nfds` argument is less than 0 or greater than FD_SETSIZE.

**EXAMPLES**

None.

**APPLICATION USAGE**

The use of `select()` and `pselect()` requires that the application construct the set of file descriptors to work on each time through a polling loop, and is inherently limited from operating on file descriptors larger than FD_SETSIZE. Also, the amount of work to perform scales as `nfds` increases, even if the number of file descriptors selected within the larger set remains the same. Thus, applications may wish to consider using `poll()` and `ppoll()` instead, for better scaling.

**RATIONALE**

In earlier versions of the Single UNIX Specification, the `select()` function was defined in the `<sys/time.h>` header. This is now changed to `<sys/select.h>`. The rationale for this change was as follows: the introduction of the `pselect()` function included the `<sys/select.h>` header and the `<sys/select.h>` header defines all the related definitions for the `pselect()` and `select()` functions. Backwards-compatibility to existing XSI implementations is handled by allowing `<sys/time.h>` to include `<sys/select.h>`.

Code which wants to avoid the ambiguity of the signal mask for thread cancellation handlers can install an additional cancellation handler which resets the signal mask to the expected value.

```c
void cleanup(void *arg)
{
    sigset_t *ss = (sigset_t *) arg;
    pthread_sigmask(SIG_SETMASK, ss, NULL);
}

int call_pselect(int nfds, fd_set *readfds, fd_set *writefds,
                 fd_set *errorfds, const struct timespec *timeout,
                 const sigset_t *sigmask)
{
    sigset_t oldmask;
    int result;
```
NAME

pthread_cond_broadcast, pthread_cond_signal — broadcast or signal a condition

SYNOPSIS

#include <pthread.h>

int pthread_cond_broadcast(pthread_cond_t *cond);
int pthread_cond_signal(pthread_cond_t *cond);

DESCRIPTION

These functions shall unblock threads blocked on a condition variable.

The pthread_cond_broadcast() function shall unblock all threads currently blocked on the
specified condition variable cond.

The pthread_cond_signal() function shall unblock at least one of the threads that are blocked on
the specified condition variable cond (if any threads are blocked on cond).

If more than one thread is blocked on a condition variable, the scheduling policy shall determine
the order in which threads are unblocked. When each thread unblocked as a result of a
pthread_cond_broadcast() or pthread_cond_signal() returns from its call to pthread_cond_clockwait(),
pthread_cond_timedwait(), or pthread_cond_wait(), the thread shall own the mutex with which it
is called pthread_cond_clockwait(), pthread_cond_timedwait(), or pthread_cond_wait(). The thread(s)
that are unblocked shall contend for the mutex according to the scheduling policy (if applicable),
and as if each had called pthread_mutex_lock().

The pthread_cond_broadcast() or pthread_cond_signal() functions may be called by a thread
whether or not it currently owns the mutex that threads calling pthread_cond_clockwait(),
pthread_cond_timedwait(), or pthread_cond_wait() have associated with the condition variable
during their waits; however, if predictable scheduling behavior is required, then that mutex shall
be locked by the thread calling pthread_cond_broadcast() or pthread_cond_signal().

The pthread_cond_broadcast() and pthread_cond_signal() functions shall have no effect if there are
no threads currently blocked on cond.

The behavior is undefined if the value specified by the cond argument to pthread_cond_broadcast()
or pthread_cond_signal() does not refer to an initialized condition variable.

RETURN VALUE

If successful, the pthread_cond_broadcast() and pthread_cond_signal() functions shall return zero;
otherwise, an error number shall be returned to indicate the error.

ERRORS

These functions shall not return an error code of [EINTR].

EXAMPLES

None.

APPLICATION USAGE

The pthread_cond_broadcast() function is used whenever the shared-variable state has been
changed in a way that more than one thread can proceed with its task. Consider a single
producer/multiple consumer problem, where the producer can insert multiple items on a list
that is accessed one item at a time by the consumers. By calling the pthread_cond_broadcast()
function, the producer would notify all consumers that might be waiting, and thereby the
application would receive more throughput on a multi-processor. In addition,
pthread_cond_broadcast() makes it easier to implement a read-write lock. The
pthread_cond_broadcast() function is needed in order to wake up all waiting readers when a
writer releases its lock. Finally, the two-phase commit algorithm can use this broadcast function
to notify all clients of an impending transaction commit.
It is not safe to use the `pthread_cond_signal()` function in a signal handler that is invoked asynchronously. Even if it were safe, there would still be a race between the test of the Boolean `pthread_cond_wait()` that could not be efficiently eliminated.

Mutexes and condition variables are thus not suitable for releasing a waiting thread by signaling from code running in a signal handler.

**RATIONALE**

If an implementation detects that the value specified by the `cond` argument to `pthread_cond_broadcast()` or `pthread_cond_signal()` does not refer to an initialized condition variable, it is recommended that the function should fail and report an `[EINVAL]` error.

**Multiple Awakenings by Condition Signal**

On a multi-processor, it may be impossible for an implementation of `pthread_cond_signal()` to avoid the unblocking of more than one thread blocked on a condition variable. For example, consider the following partial implementation of `pthread_cond_wait()` and `pthread_cond_signal()`, executed by two threads in the order given. One thread is trying to wait on the condition variable, another is concurrently executing `pthread_cond_signal()`, while a third thread is already waiting.

```c
pthread_cond_wait(mutex, cond):
    value = cond->value; /* 1 */
    pthread_mutex_unlock(mutex); /* 2 */
    pthread_mutex_lock(cond->mutex); /* 10 */
    if (value == cond->value) { /* 11 */
        me->next_cond = cond->waiter;
        cond->waiter = me;
        pthread_mutex_unlock(cond->mutex);
        unable_to_run(me);
    } else
    pthread_mutex_unlock(cond->mutex); /* 12 */
    pthread_mutex_lock(mutex); /* 13 */

pthread_cond_signal(cond):
    pthread_mutex_lock(cond->mutex); /* 3 */
    cond->value++; /* 4 */
    if (cond->waiter) { /* 5 */
        sleeper = cond->waiter; /* 6 */
        cond->waiter = sleeper->next_cond; /* 7 */
        able_to_run(sleeper); /* 8 */
    }
    pthread_mutex_unlock(cond->mutex); /* 9 */
```

The effect is that more than one thread can return from its call to `pthread_cond_clockwait()`, `pthread_cond_timedwait()`, or `pthread_cond_wait()` as a result of one call to `pthread_cond_signal()`. This effect is called “spurious wakeup”. Note that the situation is self-correcting in that the number of threads that are so awakened is finite; for example, the next thread to call `pthread_cond_wait()` after the sequence of events above blocks.

While this problem could be resolved, the loss of efficiency for a fringe condition that occurs only rarely is unacceptable, especially given that one has to check the predicate associated with a condition variable anyway. Correcting this problem would unnecessarily reduce the degree of concurrency in this basic building block for all higher-level synchronization operations.

An added benefit of allowing spurious wakeups is that applications are forced to code a
NAME

pthread_cond_clockwait, pthread_cond_timedwait, pthread_cond_wait — wait on a condition

SYNOPSIS

#include <pthread.h>

int pthread_cond_clockwait(pthread_cond_t *restrict cond,
    pthread_mutex_t *restrict mutex, clockid_t clock_id,
    const struct timespec *restrict abstime);

int pthread_cond_timedwait(pthread_cond_t *restrict cond,
    pthread_mutex_t *restrict mutex,
    const struct timespec *restrict abstime);

int pthread_cond_wait(pthread_cond_t *restrict cond,
    pthread_mutex_t *restrict mutex);

DESCRIPTION

The pthread_cond_clockwait(), pthread_cond_timedwait(), and pthread_cond_wait() functions shall
block on a condition variable. The application shall ensure that these functions are called with
mutex locked by the calling thread; otherwise, an error (for PTHREAD_MUTEX_ERRORCHECK
and robust mutexes) or undefined behavior (for other mutexes) results.

These functions atomically release mutex and cause the calling thread to block on the condition
variable cond; atomically here means “atomically with respect to access by another thread to the
mutex and then the condition variable”. That is, if another thread is able to acquire the mutex
after the about-to-block thread has released it, then a subsequent call to pthread_cond_broadcast()
or pthread_cond_signal() in that thread shall behave as if it were issued after the about-to-block
thread has blocked.

Upon successful return, the mutex shall have been locked and shall be owned by the calling
thread.

If mutex is a robust mutex where an owner terminated while holding the lock and the state is
recoverable, the mutex shall be acquired even though the function returns [EOWNERDEAD].

When using condition variables there is always a Boolean predicate involving shared variables
associated with each condition wait that is true if the thread should proceed. Spurious wakeups
from the pthread_cond_clockwait(), pthread_cond_timedwait(), or pthread_cond_wait() functions
may occur. Since the return from pthread_cond_clockwait(), pthread_cond_timedwait(), or
pthread_cond_wait() does not imply anything about the value of this predicate, the predicate
should be re-evaluated upon such return.

When a thread waits on a condition variable, having specified a particular mutex to the
pthread_cond_clockwait(), pthread_cond_timedwait(), or pthread_cond_wait() operation, a dynamic
binding is formed between that mutex and condition variable that remains in effect as long as at
least one thread is blocked on the condition variable. During this time, the effect of an attempt
by any thread to wait on that condition variable using a different mutex is undefined. Once all
waiting threads have been unblocked (as by the pthread_cond_broadcast() operation), the next
wait operation on that condition variable shall form a new dynamic binding with the mutex
specified by that wait operation. Even though the dynamic binding between condition variable
and mutex may be removed or replaced between the time a thread is unblocked from a wait on
the condition variable and the time that it returns to the caller or begins cancellation cleanup, the
unblocked thread shall always re-acquire the mutex specified in the condition wait operation
call from which it is returning.

A condition wait (whether timed or not) is a cancellation point. When the cancelability type of a
thread is set to PTHREAD_CANCEL_DEFERRED, a side-effect of acting upon a cancellation
request while in a condition wait is that the mutex is (in effect) re-acquired before calling the first
cancellation cleanup handler. The effect is as if the thread were unblocked, allowed to execute up
to the point of returning from the call to `pthread_cond_clockwait()`, `pthread_cond_timedwait()`, or
`pthread_cond_wait()`, but at that point notices the cancellation request and, instead of returning to
the caller, starts the thread cancellation activities, which includes calling cancellation cleanup
handlers.

A thread that has been unblocked because it has been canceled while blocked in a call to
`pthread_cond_clockwait()`, `pthread_cond_timedwait()`, or `pthread_cond_wait()` shall not consume any
condition signal that may be directed concurrently at the condition variable if there are other
threads blocked on the condition variable.

The `pthread_cond_timedwait()` function shall be equivalent to `pthread_cond_wait()`, except that an
error is returned if the absolute time specified by `abstime` passes (that is, system time equals or
exceeds `abstime`) before the condition `cond` is signaled or broadcasted, or if the absolute time
specified by `abstime` has already been passed at the time of the call. When such timeouts occur,
`pthread_cond_timedwait()` shall nonetheless release and re-acquire the mutex referenced by `mutex`,
and may consume a condition signal directed concurrently at the condition variable.

The condition variable shall have a clock attribute which specifies the clock that shall be used by
`pthread_cond_timedwait()` to measure the time specified by the `abstime` argument. The
`pthread_cond_timedwait()` function is also a cancellation point.

The `pthread_cond_clockwait()` function shall be equivalent to `pthread_cond_timedwait()`, except that the absolute time specified by `abstime` is measured against the clock indicated by `clock_id` rather
than the clock specified in the condition variable’s clock attribute. Implementations shall
support passing `CLOCK_REALTIME` and `CLOCK_MONOTONIC` to `pthread_cond_clockwait()` as
the `clock_id` argument.

If a signal is delivered to a thread waiting for a condition variable, upon return from the signal
handler the thread resumes waiting for the condition variable as if it was not interrupted, or it
shall return zero due to spurious wake-up.

The behavior is undefined if the value specified by the `cond` or `mutex` argument to these
functions does not refer to an initialized condition variable or an initialized mutex object,
respectively.

RETURN VALUE

Except for `ETIMEDOUT`, `ENOTRECOVERABLE`, and `EOWNERDEAD`, all these error
checks shall act as if they were performed immediately at the beginning of processing for the
function and shall cause an error return, in effect, prior to modifying the state of the mutex
specified by `mutex` or the condition variable specified by `cond`.

Upon successful completion, a value of zero shall be returned; otherwise, an error number shall
be returned to indicate the error.

ERRORS

These functions shall fail if:

- `[EAGAIN]` The mutex is a robust mutex and the system resources available for robust
  mutexes owned would be exceeded.

- `[ENOTRECOVERABLE]` The state protected by the mutex is not recoverable.

- `[EOWNERDEAD]` The mutex is a robust mutex and the process containing the previous owning
  thread terminated while holding the mutex lock. The mutex lock shall be acquired by the calling thread and it is up to the new owner to make the state
System Interfaces

pthread_cond_timedwait()

The mutex type is PTHREAD_MUTEX_ERRORCHECK or the mutex is a robust mutex, and the current thread does not own the mutex.

The pthread_cond_clockwait() and pthread_cond_timedwait() functions shall fail if:

- [EPERM] The mutex type is PTHREAD_MUTEX_ERRORCHECK or the mutex is a robust mutex, and the current thread does not own the mutex.
- [ETIMEDOUT] The time specified by abstime has passed.
- [EINVAL] The abstime argument specified a nanosecond value less than zero or greater than or equal to 1000 million, or the clock_id argument passed to pthread_cond_clockwait() is invalid or not supported.

These functions may fail if:

- [EOWNERDEAD] The mutex is a robust mutex and the previous owning thread terminated while holding the mutex lock. The mutex lock shall be acquired by the calling thread and it is up to the new owner to make the state consistent.

These functions shall not return an error code of [EINVAL].

EXAMPLES

None.

APPLICATION USAGE

Applications that have assumed that non-zero return values are errors will need updating for use with robust mutexes, since a valid return for a thread acquiring a mutex which is protecting a currently inconsistent state is [EOWNERDEAD]. Applications that do not check the error returns, due to ruling out the possibility of such errors arising, should not use robust mutexes. If an application is supposed to work with normal and robust mutexes, it should check all return values for error conditions and if necessary take appropriate action.

RATIONALE

If an implementation detects that the value specified by the cond argument to pthread_cond_clockwait(), pthread_cond_timedwait(), or pthread_cond_wait() does not refer to an initialized condition variable, or detects that the value specified by the mutex argument does not refer to an initialized mutex object, it is recommended that the function should fail and report an [EINVAL] error.

Condition Wait Semantics

It is important to note that when pthread_cond_clockwait(), pthread_cond_timedwait(), and pthread_cond_wait() return without error, the associated predicate may still be false. Similarly, when pthread_cond_clockwait() or pthread_cond_timedwait() returns with the timeout error, the associated predicate may be true due to an unavoidable race between the expiration of the timeout and the predicate state change.

The application needs to recheck the predicate on any return because it cannot be sure there is another thread waiting on the thread to handle the signal, and if there is not then the signal is lost. The burden is on the application to check the predicate.

Some implementations, particularly on a multi-processor, may sometimes cause multiple threads to wake up when the condition variable is signaled simultaneously on different processors.

In general, whenever a condition wait returns, the thread has to re-evaluate the predicate associated with the condition wait to determine whether it can safely proceed, should wait again, or should declare a timeout. A return from the wait does not imply that the associated
predicate is either true or false.

It is thus recommended that a condition wait be enclosed in the equivalent of a "while loop" that checks the predicate.

**Timed Wait Semantics**

An absolute time measure was chosen for specifying the timeout parameter for two reasons. First, a relative time measure can be easily implemented on top of a function that specifies absolute time, but there is a race condition associated with specifying an absolute timeout on top of a function that specifies relative timeouts. For example, assume that `clock_gettime()` returns the current time and `cond_relative_timed_wait()` uses relative timeouts:

```c
    clock_gettime(CLOCK_REALTIME, &now);
    reltime = sleep_til_this_absolute_time -now;
    cond_relative_timed_wait(c, m, &reltime);
```

If the thread is preempted between the first statement and the last statement, the thread blocks for too long. Blocking, however, is irrelevant if an absolute timeout is used. An absolute timeout also need not be recomputed if it is used multiple times in a loop, such as that enclosing a condition wait.

For cases when the system clock is advanced discontinuously by an operator, it is expected that implementations process any timed wait expiring at an intervening time as if that time had actually occurred.

**Choice of Clock**

Care should be taken to decide which clock is most appropriate when waiting with a timeout. The system clock `CLOCK_REALTIME`, as used by default with `pthread_cond_timedwait()`, may be subject to jumps forwards and backwards in order to correct it against actual time. `CLOCK_MONOTONIC` is guaranteed not to jump backwards and must also advance in real time, so using it via `pthread_cond_clockwait()` or `pthread_condattr_setclock()` may be more appropriate.

**Cancellation and Condition Wait**

A condition wait, whether timed or not, is a cancellation point. That is, the functions `cond_clock_wait()`, `cond_timed_wait()`, and `cond_wait()` are points where a pending (or concurrent) cancellation request is noticed. The reason for this is that an indefinite wait is possible at these points—whatever event is being waited for, even if the program is totally correct, might never occur; for example, some input data being awaited might never be sent. By making condition wait a cancellation point, the thread can be canceled and perform its cancellation cleanup handler even though it may be stuck in some indefinite wait.

A side-effect of acting on a cancellation request while a thread is blocked on a condition variable is to re-acquire the mutex before calling any of the cancellation cleanup handlers. This is done in order to ensure that the cancellation cleanup handler is executed in the same state as the critical code that lies both before and after the call to the condition wait function. This rule is also required when interfacing to POSIX threads from languages, such as Ada or C++, which may choose to map cancellation onto a language exception; this rule ensures that each exception handler guarding a critical section can always safely depend upon the fact that the associated mutex has already been locked regardless of exactly where within the critical section the exception was raised. Without this rule, there would not be a uniform rule that exception handlers could follow regarding the lock, and so coding would become very cumbersome.
Timed Condition Wait

The `pthread_cond_clockwait()` and `pthread_cond_timedwait()` functions allow an application to give up waiting for a particular condition after a given amount of time. An example follows:

```c
(void) pthread_mutex_lock(&t.mn);
  t.waiters++;
  clock_gettime(CLOCK_MONOTONIC, &ts);
  ts.tv_sec += 5;
  rc = 0;
  while (! mypredicate(&t) && rc == 0)
    rc = pthread_cond_clockwait(&t.cond, &t.mn, 
                                CLOCK_MONOTONIC, &ts);
  t.waiters--;
  if (rc == 0 || mypredicate(&t))
    setmystate(&t);
(void) pthread_mutex_unlock(&t.mn);
```

By making the timeout parameter absolute, it does not need to be recomputed each time the program checks its blocking predicate. If the timeout was relative, it would have to be recomputed before each call. This would be especially difficult since such code would need to take into account the possibility of extra wakeups that result from extra broadcasts or signals on the condition variable that occur before either the predicate is true or the timeout is due. Using `CLOCK_MONOTONIC` rather than `CLOCK_REALTIME` means that the timeout is not influenced by the system clock being changed.

FUTURE DIRECTIONS
None.

SEE ALSO
`pthread_cond_broadcast()`

XBD Section 4.13 (on page 91), `<pthread.h>`

CHANGE HISTORY
First released in Issue 5. Included for alignment with the POSIX Threads Extension.

Issue 6
The `pthread_cond_timedwait()` and `pthread_cond_wait()` functions are marked as part of the Threads option.

The Open Group Corrigendum U021/9 is applied, correcting the prototype for the `pthread_cond_wait()` function.

The DESCRIPTION is updated for alignment with IEEE Std 1003.1j-2000 by adding semantics for the Clock Selection option.

The ERRORS section has an additional case for [EPERM] in response to IEEE PASC Interpretation 1003.1c #28.

The restrict keyword is added to the `pthread_cond_timedwait()` and `pthread_cond_wait()` prototypes for alignment with the ISO/IEC 9899:1999 standard.

IEEE Std 1003.1-2001/Cor 2-2004, item XSH/TC2/D6/89 is applied, updating the DESCRIPTION for consistency with the `pthread_cond_destroy()` function that states it is safe to destroy an initialized condition variable upon which no threads are currently blocked.

IEEE Std 1003.1-2001/Cor 2-2004, item XSH/TC2/D6/90 is applied, updating words in the DESCRIPTION from "the cancelability enable state" to "the cancelability type".

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NAME

pthread_condattr_getclock, pthread_condattr_setclock — get and set the clock selection
condition variable attribute

SYNOPSIS

#include <pthread.h>

int pthread_condattr_getclock(const pthread_condattr_t *restrict attr,
clockid_t *restrict clock_id);

int pthread_condattr_setclock(pthread_condattr_t *attr,
clockid_t clock_id);

DESCRIPTION

The pthread_condattr_getclock() function shall obtain the value of the clock attribute from the
attributes object referenced by attr.

The pthread_condattr_setclock() function shall set the clock attribute in an initialized attributes
object referenced by attr. If pthread_condattr_setclock() is called with a clock_id argument that
refers to a CPU-time clock, the call shall fail.

The clock attribute is the clock ID of the clock that shall be used to measure the timeout service of
pthread_cond_timedwait(). The default value of the clock attribute shall refer to the system clock.
The clock attribute shall have no effect on the pthread_cond_clockwait() function.

The behavior is undefined if the value specified by the attr argument to
pthread_condattr_getclock() or pthread_condattr_setclock() does not refer to an initialized condition
variable attributes object.

RETURN VALUE

If successful, the pthread_condattr_getclock() function shall return zero and store the value of the
clock attribute of attr into the object referenced by the clock_id argument. Otherwise, an error
number shall be returned to indicate the error.

If successful, the pthread_condattr_setclock() function shall return zero; otherwise, an error
number shall be returned to indicate the error.

ERRORS

The pthread_condattr_setclock() function may fail if:

[EINVAL] The value specified by clock_id does not refer to a known clock, or is a CPU-
time clock.

These functions shall not return an error code of [EINTR].

EXAMPLES

None.

APPLICATION USAGE

None.

RATIONALE

If an implementation detects that the value specified by the attr argument to
pthread_condattr_getclock() or pthread_condattr_setclock() does not refer to an initialized condition
variable attributes object, it is recommended that the function should fail and report an
[EINVAL] error.
NAME

pthread_mutex_destroy, pthread_mutex_init — destroy and initialize a mutex

SYNOPSIS

#include <pthread.h>

int pthread_mutex_destroy(pthread_mutex_t *mutex);

int pthread_mutex_init(pthread_mutex_t *restrict mutex,
                     const pthread_mutexattr_t *restrict attr);

pthread_mutex_t mutex = PTHREAD_MUTEX_INITIALIZER;

DESCRIPTION

The pthread_mutex_destroy() function shall destroy the mutex object referenced by mutex; the
mutex object becomes, in effect, uninitialized. An implementation may cause
pthread_mutex_destroy() to set the object referenced by mutex to an invalid value.

A destroyed mutex object can be reinitialized using pthread_mutex_init(); the results of otherwise
referencing the object after it has been destroyed are undefined.

It shall be safe to destroy an initialized mutex that is unlocked. Attempting to destroy a locked
mutex, or a mutex that another thread is attempting to lock, or a mutex that is being used in a
pthread_cond_clockwait(), pthread_cond_timedwait(), or pthread_cond_wait() call by another thread,
results in undefined behavior.

The pthread_mutex_init() function shall initialize the mutex referenced by mutex with attributes
specified by attr. If attr is NULL, the default mutex attributes are used; the effect shall be the
same as passing the address of a default mutex attributes object. Upon successful initialization,
the state of the mutex becomes initialized and unlocked.

See Section 2.9.9 (on page 508) for further requirements.

Attempting to initialize an already initialized mutex results in undefined behavior.

In cases where default mutex attributes are appropriate, the macro
PTHREAD_MUTEX_INITIALIZER can be used to initialize mutexes. The effect shall be
equivalent to dynamic initialization by a call to pthread_mutex_init() with parameter attr
specified as NULL, except that no error checks are performed.

The behavior is undefined if the value specified by the mutex argument to
pthread_mutex_destroy() does not refer to an initialized mutex.

The behavior is undefined if the value specified by the attr argument to pthread_mutex_init()
do not refer to an initialized mutex attributes object.

RETURN VALUE

If successful, the pthread_mutex_destroy() and pthread_mutex_init() functions shall return zero;
otherwise, an error number shall be returned to indicate the error.

ERRORS

The pthread_mutex_init() function shall fail if:

[EAGAIN] The system lacked the necessary resources (other than memory) to initialize
another mutex.

[ENOMEM] Insufficient memory exists to initialize the mutex.

[EPERM] The caller does not have the privilege to perform the operation.
The `pthread_mutex_init()` function may fail if:

- **[EINVAL]** The attributes object referenced by `attr` has the robust mutex attribute set without the process-shared attribute being set.

These functions shall not return an error code of [EINTR].

**EXAMPLES**

None.

**APPLICATION USAGE**

None.

**RATIONALE**

If an implementation detects that the value specified by the `mutex` argument to `pthread_mutex_destroy()` does not refer to an initialized mutex, it is recommended that the function should fail and report an [EINVAL] error.

If an implementation detects that the value specified by the `mutex` argument to `pthread_mutex_destroy()` or `pthread_mutex_init()` refers to a locked mutex or a mutex that is referenced (for example, while being used in `pthread_cond_clockwait()`, `pthread_cond_timedwait()`, or `pthread_cond_wait()` call) by another thread, or detects that the value specified by the `mutex` argument to `pthread_mutex_init()` refers to an already initialized mutex, it is recommended that the function should fail and report an [EBUSY] error.

If an implementation detects that the value specified by the `attr` argument to `pthread_mutex_init()` does not refer to an initialized mutex attributes object, it is recommended that the function should fail and report an [EINVAL] error.

**Alternate Implementations Possible**

This volume of POSIX.1-202x supports several alternative implementations of mutexes. An implementation may store the lock directly in the object of type `pthread_mutex_t`. Alternatively, an implementation may store the lock in the heap and merely store a pointer, handle, or unique ID in the mutex object. Either implementation has advantages or may be required on certain hardware configurations. So that portable code can be written that is invariant to this choice, this volume of POSIX.1-202x does not define assignment or equality for this type, and it uses the term "initialize" to reinforce the (more restrictive) notion that the lock may actually reside in the mutex object itself.

Note that this precludes an over-specification of the type of the mutex or condition variable and motivates the opaqueness of the type.

An implementation is permitted, but not required, to have `pthread_mutex_destroy()` store an illegal value into the mutex. This may help detect erroneous programs that try to lock (or otherwise reference) a mutex that has already been destroyed.

**Tradeoff Between Error Checks and Performance Supported**

Many error conditions that can occur are not required to be detected by the implementation in order to let implementations trade off performance versus degree of error checking according to the needs of their specific applications and execution environment. As a general rule, conditions caused by the system (such as insufficient memory) are required to be detected, but conditions caused by an erroneously coded application (such as failing to provide adequate synchronization to prevent a mutex from being deleted while in use) are specified to result in undefined behavior.

A wide range of implementations is thus made possible. For example, an implementation...
particular, it can happen at most as many times as there are statically allocated synchronization objects. Dynamically allocated objects would still be initialized via
 pthread_mutex_init() or
 pthread_cond_init().

Finally, if none of the above optimization techniques for out-of-line allocation yields sufficient performance for an application on some implementation, the application can avoid static initialization altogether by explicitly initializing all synchronization objects with the corresponding pthread_*_init() functions, which are supported by all implementations. An implementation can also document the tradeoffs and advise which initialization technique is more efficient for that particular implementation.

Destroying Mutexes

A mutex can be destroyed immediately after it is unlocked. However, since attempting to destroy a locked mutex, or a mutex that another thread is attempting to lock, or a mutex that is being used in a pthread_cond_clockwait(), pthread_cond_timedwait(), or pthread_cond_wait() call by another thread, results in undefined behavior, care must be taken to ensure that no other thread may be referencing the mutex.

Robust Mutexes

Implementations are required to provide robust mutexes for mutexes with the process-shared attribute set to PTHREAD_PROCESS_SHARED. Implementations are allowed, but not required, to provide robust mutexes when the process-shared attribute is set to PTHREAD_PROCESS_PRIVATE.

FUTURE DIRECTIONS

None.

SEE ALSO

pthread_mutex_getprioceiling(), pthread_mutexattr_getrobust(), pthread_mutex_lock(),
 pthread_mutex_timedlock(), pthread_mutexattr_getpshared()

XBD <pthread.h>

CHANGE HISTORY

First released in Issue 5. Included for alignment with the POSIX Threads Extension.

Issue 6

The pthread_mutex_destroy() and pthread_mutex_init() functions are marked as part of the Threads option.

The pthread_mutex_timedlock() function is added to the SEE ALSO section for alignment with IEEE Std 1003.1d-1999.

IEEE PASC Interpretation 1003.1c #34 is applied, updating the DESCRIPTION.

The restrict keyword is added to the pthread_mutex_init() prototype for alignment with the ISO/IEC 9899:1999 standard.

Issue 7

Changes are made from The Open Group Technical Standard, 2006, Extended API Set Part 3.

The pthread_mutex_destroy() and pthread_mutex_init() functions are moved from the Threads option to the Base.

The [EINVAL] error for an uninitialized mutex or an uninitialized mutex attributes object is removed; this condition results in undefined behavior.
NAME

pthread_mutex_clocklock, pthread_mutex_timedlock — lock a mutex

SYNOPSIS

#include <pthread.h>

int pthread_mutex_clocklock(pthread_mutex_t *restrict mutex, +
clockid_t clock_id, const struct timespec *restrict abstime); +
int pthread_mutex_timedlock(pthread_mutex_t *restrict mutex, +
const struct timespec *restrict abstime);

DESCRIPTION

The pthread_mutex_clocklock() and pthread_mutex_timedlock() functions shall lock the mutex object referenced by mutex. If the mutex is already locked, the calling thread shall block until the mutex becomes available as in the pthread_mutex_lock() function. If the mutex cannot be locked without waiting for another thread to unlock the mutex, this wait shall be terminated when the specified timeout expires.

The timeout shall expire when the absolute time specified by abstime passes, as measured by the clock on which timeouts are based (that is, when the value of that clock equals or exceeds abstime), or if the absolute time specified by abstime has already been passed at the time of the call.

For pthread_mutex_timedlock(), the timeout shall be based on the CLOCK_REALTIME clock. For pthread_mutex_clocklock(), the timeout shall be based on the clock specified by the clock_id argument. The resolution of the timeout shall be the resolution of the clock on which it is based. Implementations shall support passing CLOCK_REALTIME and CLOCK_MONOTONIC to pthread_mutex_clocklock() as the clock_id argument.

Under no circumstance shall the function fail with a timeout if the mutex can be locked immediately. The validity of the abstime parameter need not be checked if the mutex can be locked immediately.

As a consequence of the priority inheritance rules (for mutexes initialized with the PRIO_INHERIT protocol), if a timed mutex wait is terminated because its timeout expires, the priority of the owner of the mutex shall be adjusted as necessary to reflect the fact that this thread is no longer among the threads waiting for the mutex.

If mutex is a robust mutex and the process containing the owning thread terminated while holding the mutex lock, a call to pthread_mutex_clocklock() or pthread_mutex_timedlock() shall return the error value [EOWNERDEAD]. If mutex is a robust mutex and the owning thread terminated while holding the mutex lock, a call to pthread_mutex_clocklock() or pthread_mutex_timedlock() may return the error value [EOWNERDEAD] even if the process in which the owning thread resides has not terminated. In these cases, the mutex is locked by the thread but the state it protects is marked as inconsistent. The application should ensure that the state is made consistent for reuse and that is complete call pthread_mutex_consistent(). If the application is unable to recover the state, it should unlock the mutex without a prior call to pthread_mutex_consistent(), after which the mutex is marked permanently unusable.

If mutex does not refer to an initialized mutex object, the behavior is undefined.

RETURN VALUE

If successful, the pthread_mutex_clocklock() and pthread_mutex_timedlock() functions shall return zero; otherwise, an error number shall be returned to indicate the error.
ERRORS

The pthread_mutex_clocklock() and pthread_mutex_timedlock() functions shall fail if:

[EAGAIN] The mutex could not be acquired because the maximum number of recursive locks for mutex has been exceeded.

[EAGAIN] The mutex is a robust mutex and the system resources available for robust mutexes owned would be exceeded.

[EDEADLK] The mutex type is PTHREAD_MUTEX_ERRORCHECK and the current thread already owns the mutex.

[EDEADLK] A deadlock condition was detected.

[EOWNERDEAD] The mutex is a robust mutex and the previous owning thread terminated while holding the mutex lock. The mutex lock shall be acquired by the calling thread and it is up to the new owner to make the state consistent.

ETIMEDOUT] The mutex could not be locked before the specified timeout expired.

The pthread_mutex_clocklock() and pthread_mutex_timedlock() functions may fail if:

[EDEADLK] A deadlock condition was detected.

[EOWNERDEAD] The mutex is a robust mutex and the previous owning thread terminated while holding the mutex lock. The mutex lock shall be acquired by the calling thread and it is up to the new owner to make the state consistent.

This function shall not return an error code of [EINTR].

EXAMPLES

None.

APPLICATION USAGE

Applications that have assumed that non-zero return values are errors will need updating for use with robust mutexes, since a valid return for a thread acquiring a mutex which is protecting a currently inconsistent state is [EOWNERDEAD]. Applications that do not check the error returns, due to ruling out the possibility of such errors arising, should not use robust mutexes. If an application is supposed to work with normal and robust mutexes, it should check all return values for error conditions and if necessary take appropriate action.

RATIONALE

Refer to pthread_mutex_lock().
NAME

pthread_mutexattr_gettype, pthread_mutexattr_settype — get and set the mutex type attribute

SYNOPSIS

#include <pthread.h>

int pthread_mutexattr_gettype(const pthread_mutexattr_t *restrict attr, int *restrict type);
int pthread_mutexattr_settype(pthread_mutexattr_t *attr, int type);

DESCRIPTION

The pthread_mutexattr_gettype() and pthread_mutexattr_settype() functions, respectively, shall get and set the mutex type attribute. This attribute is set in the type parameter to these functions. The default value of the type attribute is PTHREAD_MUTEX_DEFAULT.

The type of mutex is contained in the type attribute of the mutex attributes. Valid mutex types include:

PTHREAD_MUTEX_NORMAL
PTHREAD_MUTEX_ERRORCHECK
PTHREAD_MUTEX_RECURSIVE
PTHREAD_MUTEX_DEFAULT

The mutex type affects the behavior of calls which lock and unlock the mutex. See pthread_mutex_lock() for details. An implementation may map PTHREAD_MUTEX_DEFAULT to one of the other mutex types.

The behavior is undefined if the value specified by the attr argument to pthread_mutexattr_gettype() or pthread_mutexattr_settype() does not refer to an initialized mutex attributes object.

RETURN VALUE

Upon successful completion, the pthread_mutexattr_gettype() function shall return zero and store the value of the type attribute of attr into the object referenced by the type parameter. Otherwise, an error shall be returned to indicate the error.

If successful, the pthread_mutexattr_settype() function shall return zero; otherwise, an error number shall be returned to indicate the error.

ERRORS

The pthread_mutexattr_settype() function shall fail if:

[EINVAL] The value type is invalid.

These functions shall not return an error code of [EINTR].

EXAMPLES

None.

APPLICATION USAGE

It is advised that an application should not use a PTHREAD_MUTEX_RECURSIVE mutex with condition variables because the implicit unlock performed in a pthread_cond_clockwait(), pthread_cond_timedwait(), or pthread_cond_wait() call may not actually release the mutex (if it had been locked multiple times). If this happens, no other thread can satisfy the condition of the predicate.
NAME

pthread_rwlock_clockrdlock, pthread_rwlock_timedrdlock — lock a read-write lock for reading

SYNOPSIS

#include <pthread.h>

int pthread_rwlock_clockrdlock(pthread_rwlock_t *restrict rwlock, clockid_t clock_id, const struct timespec *restrict abstime);

int pthread_rwlock_timedrdlock(pthread_rwlock_t *restrict rwlock, const struct timespec *restrict abstime);

DESCRIPTION

The pthread_rwlock_clockrdlock() and pthread_rwlock_timedrdlock() functions shall apply a read lock to the read-write lock referenced by rwlock as in the pthread_rwlock_rdlock() function. However, if the lock cannot be acquired without waiting for other threads to unlock the lock, this wait shall be terminated when the specified timeout expires. The timeout shall expire when the absolute time specified by abstime passes, as measured by the clock on which timeouts are based (that is, when the value of that clock equals or exceeds abstime), or if the absolute time specified by abstime has already been passed at the time of the call.

For pthread_rwlock_timedrdlock(), the timeout shall be based on the CLOCK_REALTIME clock. For pthread_rwlock_clockrdlock(), the timeout shall be based on the clock specified by the clock_id argument. The resolution of the timeout shall be the resolution of the clock on which it is based. Implementations shall support passing CLOCK_REALTIME and CLOCK_MONOTONIC to pthread_rwlock_clockrdlock() as the clock_id argument.

Under no circumstances shall the function fail with a timeout if the lock can be acquired immediately. The validity of the abstime parameter need not be checked if the lock can be immediately acquired.

If a signal that causes a signal handler to be executed is delivered to a thread blocked on a read-write lock via a call to pthread_rwlock_clockrdlock() or pthread_rwlock_timedrdlock(), upon return from the signal handler the thread shall resume waiting for the lock as if it was not interrupted.

The calling thread may deadlock if at the time the call is made it holds a write lock on rwlock. The results are undefined if this function is called with an uninitialized read-write lock.

RETURN VALUE

The pthread_rwlock_clockrdlock() and pthread_rwlock_timedrdlock() functions shall return zero if the lock for reading on the read-write lock object referenced by rwlock is acquired. Otherwise, an error number shall be returned to indicate the error.

ERRORS

The pthread_rwlock_clockrdlock() and pthread_rwlock_timedrdlock() functions shall fail if:

[ETIMEDOUT] The lock could not be acquired before the specified timeout expired.

The pthread_rwlock_clockrdlock() and pthread_rwlock_timedrdlock() functions may fail if:

[EAGAIN] The read lock could not be acquired because the maximum number of read locks for lock would be exceeded.

[EDEADLK] A deadlock condition was detected or the calling thread already holds a write lock on rwlock.

[EINVAL] The abstime nanosecond value is less than zero or greater than or equal to 1,000 million, or the pthread_rwlock_clockrdlock() function was passed an invalid or unsupported clock_id value.

This function shall not return an error code of [EINVAL].
EXAMPLES

None.

APPLICATION USAGE

Applications using this function may be subject to priority inversion, as discussed in XBD Section 3.260 (on page 66).

RATIONALE

If an implementation detects that the value specified by the `rwlock` argument to `pthread_rwlock_clockrdlock()` or `pthread_rwlock_timedrdlock()` does not refer to an initialized read-write lock object, it is recommended that the function should fail and report an [EINVAL] error.

FUTURE DIRECTIONS

None.

SEE ALSO

`pthread_rwlock_destroy()`, `pthread_rwlock_rdlock()`, `pthread_rwlock_timedwrlock()`, `pthread_rwlock_trywrlock()`, `pthread_rwlock_unlock()`

XBD Section 3.260 (on page 66), Section 4.13 (on page 91), `<pthread.h>`, `<time.h>`

CHANGE HISTORY


IEEE Std 1003.1-2001/Cor 2-2004, item XSH/TC2/D6/102 is applied, updating the ERRORS section so that the [EDEADLK] error includes detection of a deadlock condition.

Issue 7

The `pthread_rwlock_timedrdlock()` function is moved from the Timeouts option to the Base.

The [EINVAL] error for an uninitialized read-write lock object is removed; this condition results in undefined behavior.

Issue 8

Austin Group Defect 592 is applied, removing text relating to `<time.h>` from the SYNOPSIS and DESCRIPTION sections.

Austin Group Defect 1216 is applied, adding `pthread_rwlock_clockrdlock()`.
NAME

pthread_rwlock_clockwrlock, pthread_rwlock_timedwrlock — lock a read-write lock for writing

SYNOPSIS

#include <pthread.h>

int pthread_rwlock_clockwrlock(pthread_rwlock_t *restrict rwlock, +
clockid_t clock_id, const struct timespec *restrict abstime);

int pthread_rwlock_timedwrlock(pthread_rwlock_t *restrict rwlock, +
const struct timespec *restrict abstime);

DESCRIPTION

The pthread_rwlock_clockwrlock() and pthread_rwlock_timedwrlock() functions shall apply a write lock to the read-write lock referenced by rwlock as in the pthread_rwlock_wrlock() function. However, if the lock cannot be acquired without waiting for other threads to unlock the lock, this wait shall be terminated when the specified timeout expires. The timeout shall expire when the absolute time specified by abstime passes, as measured by the clock on which timeouts are based (that is, when the value of that clock equals or exceeds abstime), or if the absolute time specified by abstime has already been passed at the time of the call.

For pthread_rwlock_timedwrlock(), the timeout shall be based on the CLOCK_REALTIME clock. For pthread_rwlock_clockwrlock(), the timeout shall be based on the clock specified by the clock_id argument. The resolution of the timeout shall be the resolution of the clock on which it is based. Implementations shall support passing CLOCK_REALTIME and CLOCK_MONOTONIC to pthread_rwlock_clockwrlock() as the clock_id argument.

Under no circumstances shall the function fail with a timeout if the lock can be acquired immediately. The validity of the abstime parameter need not be checked if the lock can be immediately acquired.

If a signal that causes a signal handler to be executed is delivered to a thread blocked on a read-write lock via a call to pthread_rwlock_clockwrlock() or pthread_rwlock_timedwrlock(), upon return from the signal handler the thread shall resume waiting for the lock as if it was not interrupted. The calling thread may deadlock if at the time the call is made it holds the read-write lock. The results are undefined if this function is called with an uninitialized read-write lock.

RETURN VALUE

The pthread_rwlock_clockwrlock() and pthread_rwlock_timedwrlock() functions shall return zero if the lock for writing on the read-write lock object referenced by rwlock is acquired. Otherwise, an error number shall be returned to indicate the error.

ERRORS

The pthread_rwlock_clockwrlock() and pthread_rwlock_timedwrlock() functions shall fail if:

[ETIMEDOUT] The lock could not be acquired before the specified timeout expired.

The pthread_rwlock_clockwrlock() and pthread_rwlock_timedwrlock() functions may fail if:

[EDEADLK] A deadlock condition was detected or the calling thread already holds the rwlock.

[EINVAL] The abstime nanosecond value is less than zero or greater than or equal to 1000 million, or the pthread_rwlock_clockwrlock() function was passed an invalid or unsupported clock_id value.

This function shall not return an error code of [EINTR].
EXAMPLES
None.

APPLICATION USAGE
Applications using this function may be subject to priority inversion, as discussed in XBD
Section 3.260 (on page 66).

RATIONALE
If an implementation detects that the value specified by the rwlock argument to
pthread_rwlock_clockwrlock() or pthread_rwlock_timedwrlock() does not refer to an initialized read-
write lock object, it is recommended that the function should fail and report an [EINVAL] error.

FUTURE DIRECTIONS
None.

SEE ALSO
pthread_rwlock_destroy(), pthread_rwlock_rdlock(), pthread_rwlock_timedrdlock(),
pthread_rwlock_trywrlock(), pthread_rwlock_unlock()

XBD Section 3.260 (on page 66), Section 4.13 (on page 91), <pthread.h>, <time.h>

CHANGE HISTORY
IEEE Std 1003.1-2001/Cor 2-2004, item XSH/TC2/D6/103 is applied, updating the ERRORS
section so that the [EDEADLK] error includes detection of a deadlock condition.

Issue 7
The pthread_rwlock_timedwrlock() function is moved from the Timeouts option to the Base.
The [EINVAL] error for an uninitialized read-write lock object is removed; this condition results
in undefined behavior.

Issue 8
Austin Group Defect 592 is applied, removing text relating to <time.h> from the SYNOPSIS and
DESCRIPTION sections.

Austin Group Defect 1216 is applied, adding pthread_rwlock_clockwrlock().
NAME
qsort, qsort_r — sort a table of data

SYNOPSIS
#include <stdlib.h>

void qsort(void *base, size_t nel, size_t width,
        int (*compar)(const void *, const void *));

CX
void qsort_r(void *base, size_t nel, size_t width,
        int (*compar)(const void *, const void *, void *), void *arg);

DESCRIPTION
For qsort(): The functionality described on this reference page is aligned with the ISO C
standard. Any conflict between the requirements described here and the ISO C standard is
unintentional. This volume of POSIX.1-202x defers to the ISO C standard.

The qsort() function shall sort an array of nel objects, the initial element of which is pointed to by
base. The size of each object, in bytes, is specified by the width argument. If the nel argument has
the value zero, the comparison function pointed to by compar shall not be called and no
rearrangement shall take place.

The application shall ensure that the comparison function pointed to by compar does not alter the
contents of the array. The implementation may reorder elements of the array between calls to the
comparison function, but shall not alter the contents of any individual element.

When the same objects (consisting of width bytes, irrespective of their current positions in the
array) are passed more than once to the comparison function, the results shall be consistent with
one another. That is, they shall define a total ordering on the array.

The contents of the array shall be sorted in ascending order according to a comparison function.
The compar argument is a pointer to the comparison function, which is called with two
arguments that point to the elements being compared. The application shall ensure that the
function returns an integer less than, equal to, or greater than 0, if the first argument is
considered respectively less than, equal to, or greater than the second. If two members compare
as equal, their order in the sorted array is unspecified.

CX
The qsort_r() function shall be identical to qsort() except that the comparison function compar
takes a third argument. The arg opaque pointer passed to qsort_r() shall in turn be passed as the
third argument to the comparison function.

RETURN VALUE
These functions shall not return a value.

ERRORS
No errors are defined.

EXAMPLES
None.

APPLICATION USAGE
The comparison function need not compare every byte, so arbitrary data may be contained in
the elements in addition to the values being compared.

If the compar callback function requires any additional state outside of the items being sorted, it
can only access this state through global variables, making it potentially unsafe to use qsort() with
the same compar function from separate threads at the same time. The qsort_r() function
was added with the ability to pass through arbitrary arguments to the comparator, which avoids
the need to access global variables and thus making it possible to safely share a stateful

Unapproved Draft, Subject to Change
comparator across threads.

**RATIONALE**
The requirement that each argument (hereafter referred to as \( p \)) to the comparison function is a pointer to elements of the array implies that for every call, for each argument separately, all of the following expressions are non-zero:

\[
((\text{char} *)p - (\text{char} *)\text{base}) \% \text{width} == 0
\]
\[
(\text{char} *)p >= (\text{char} *)\text{base}
\]
\[
(\text{char} *)p < (\text{char} *)\text{base} + \text{nel} \times \text{width}
\]

**FUTURE DIRECTIONS**
None.

**SEE ALSO**
- `alphasort()`
- XBD `<stdlib.h>`

**CHANGE HISTORY**

**Issue 6**
The normative text is updated to avoid use of the term "must" for application requirements.

**Issue 8**
IEEE Std 1003.1-2001/Cor 1-2002, item XSH/TC1/D6/49 is applied, adding the last sentence to the first non-shaded paragraph in the DESCRIPTION, and the following two paragraphs. The RATIONALE is also updated. These changes are for alignment with the ISO C standard.

Austin Group Defect 900 is applied, adding the `qsort_r()` function.
keystr[len++] = c;
keystr[len] = '\0';
printf("%s Element%0*ld\n", keystr, elementlen, i);
len = 0;
}

Generating the Same Sequence on Different Machines

The following code defines a pair of functions that could be incorporated into applications wishing to ensure that the same sequence of numbers is generated across different machines.

static unsigned long next = 1;
int myrand(void) /* RAND_MAX assumed to be 32767. */
{
    next = next * 1103515245 + 12345;
    return((unsigned)(next/65536) % 32768);
}

void mysrand(unsigned seed)
{
    next = seed;
}

APPLICATION USAGE

These functions should be avoided whenever non-trivial requirements (including safety) have to be fulfilled, unless seeded using getentropy().

The drand48() and random() functions provide much more elaborate pseudo-random number generators.

RATIONALE

The ISO C standard rand() and srand() functions allow per-process pseudo-random streams shared by all threads. Those two functions need not change, but there has to be mutual-exclusion that prevents interference between two threads concurrently accessing the random number generator.

With regard to rand(), there are two different behaviors that may be wanted in a multi-threaded program:

1. A single per-process sequence of pseudo-random numbers that is shared by all threads that call rand()

2. A different sequence of pseudo-random numbers for each thread that calls rand()

This is provided by the modified thread-safe function based on whether the seed value is global to the entire process or local to each thread.

This does not address the known deficiencies of the rand() function implementations, which have been approached by maintaining more state. In effect, this specifies new thread-safe forms of a deficient function.

FUTURE DIRECTIONS

None.
realloc()

5680  NAME
5681  realloc, reallocarray — memory reallocators

5682  SYNOPSIS
5683  #include <stdlib.h>
5684  void *realloc(void *
5685   ptr, size_t size);
5686  void *reallocarray(void *
5687   ptr, size_t nelem, size_t elsize);

5688  DESCRIPTION
5689  CX  For realloc(): The functionality described on this reference page is aligned with the ISO C standard. Any conflict between the requirements described here and the ISO C standard is unintentional. This volume of POSIX.1-202x defers to the ISO C standard.
5690  The realloc() function shall deallocate the old object pointed to by ptr and return a pointer to a new object that has the size specified by size. The contents of the new object shall be the same as that of the old object prior to deallocation, up to the lesser of the new and old sizes. Any bytes in the new object beyond the size of the old object have indeterminate values. If the size of the space requested is zero, the behavior shall be implementation-defined: either a null pointer is returned, or the behavior shall be as if the size were some non-zero value, except that the behavior is undefined if the returned pointer is used to access an object. If the space cannot be allocated, the object shall remain unchanged.
5691  CX  The reallocarray() function shall be equivalent to the call realloc(ptr, nelem * elsize) except that overflow in the multiplication shall be an error.
5692  CX  If ptr is a null pointer, realloc() or reallocarray() shall be equivalent to malloc() for the specified size.
5693  If ptr does not match a pointer earlier returned by a function in POSIX.1-202x that allocates memory as if by malloc(), or if the space has previously been deallocated by a call to free(), realloc(), or reallocarray(), the behavior is undefined.
5694  CX  The order and contiguity of storage allocated by successive calls to realloc() or reallocarray() is unspecified. The pointer returned if the allocation succeeds shall be suitably aligned so that it may be assigned to a pointer to any type of object and then used to access such an object 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 shall point to the start (lowest byte address) of the allocated space. If the space cannot be allocated, a null pointer shall be returned.
5695  RETURN VALUE
5696  CX  Upon successful completion, realloc() and reallocarray() shall return a pointer to the (possibly moved) allocated space. If size is 0, or either nelem or elsize is 0, then either:
5697  • A null pointer shall be returned and, if ptr is not a null pointer, errno shall be set to an implementation-defined value.
5698  • A pointer to the allocated space shall be returned, and the memory object pointed to by ptr shall be freed. The application shall ensure that the pointer is not used to access an object.
5699  CX  If there is not enough available memory, realloc() and reallocarray() shall return a null pointer and set errno to [ENOMEM]. If realloc() or reallocarray() returns a null pointer and errno has been set to [ENOMEM], the memory referenced by ptr shall not be changed.
The `realloc()` and `reallocarray()` functions shall fail if:

- **[ENOMEM]** Insufficient memory is available.

The `reallocarray()` function shall fail if:

- **[ENOMEM]** The calculation `nelem * elsize` would overflow.

**EXAMPLES**

None.

**APPLICATION USAGE**

The description of `realloc()` has been modified from previous versions of this standard to align with the ISO/IEC 9899:1999 standard. Previous versions explicitly permitted a call to `realloc(p, 0)` to free the space pointed to by `p` and return a null pointer. While this behavior could be interpreted as permitted by this version of the standard, the C language committee has indicated that this interpretation is incorrect. Applications should assume that if `realloc()` returns a null pointer, the space pointed to by `p` has not been freed. Since this could lead to double-frees, implementations should also set `errno` if a null pointer actually indicates a failure, and applications should only free the space if `errno` was changed.

**RATIONALE**

None.

**FUTURE DIRECTIONS**

This standard defers to the ISO C standard. While that standard currently has language that might permit `realloc(p, 0)`, where `p` is not a null pointer, to free `p` while still returning a null pointer, the committee responsible for that standard is considering clarifying the language to explicitly prohibit that alternative.

**SEE ALSO**

`calloc()`, `free()`, `malloc()`

**XBD <stdlib.h>**

**CHANGE HISTORY**

First released in Issue 1. Derived from Issue 1 of the SVID.

**Issue 6**

Extensions beyond the ISO C standard are marked.

The following new requirements on POSIX implementations derive from alignment with the Single UNIX Specification:

- In the RETURN VALUE section, if there is not enough available memory, the setting of `errno` to [ENOMEM] is added.
- The [ENOMEM] error condition is added.

**Issue 7**

POSIX.1-2008, Technical Corrigendum 1, XSH/TC1-2008/0495 [400], XSH/TC1-2008/0496 [400], XSH/TC1-2008/0497 [400], and XSH/TC1-2008/0498 [400] are applied.

NAME
sem_init — initialize an unnamed semaphore

SYNOPSIS
#include <semaphore.h>

int sem_init(sem_t *sem, int pshared, unsigned value);

DESCRIPTION
The sem_init() function shall initialize the unnamed semaphore referred to by sem. The value of
the initialized semaphore shall be value. Following a successful call to sem_init(), the semaphore
can be used in subsequent calls to sem_clockwait(), sem_destroy(), sem_post(), sem_timedwait(),
sem_trywait(), and sem_wait(). This semaphore shall remain usable until the semaphore is
destroyed. An unnamed semaphore may be implemented using a file descriptor.

If the pshared argument has a non-zero value, then the semaphore is shared between processes;
in this case, any process that can access the semaphore sem can use sem for performing
sem_clockwait(), sem_destroy(), sem_post(), sem_timedwait(), sem_trywait(), and sem_wait()
operations.

If the pshared argument is zero, then the semaphore is shared between threads of the process; any
thread in this process can use sem for performing sem_clockwait(), sem_destroy(), sem_post(),
sem_timedwait(), sem_trywait(), and sem_wait() operations.

See Section 2.9.9 (on page 508) for further requirements.

Attempting to initialize an already initialized semaphore results in undefined behavior.

RETURN VALUE
Upon successful completion, the sem_init() function shall initialize the semaphore in sem and
return 0. Otherwise, it shall return −1 and set errno to indicate the error.

ERRORS
The sem_init() function shall fail if:

EINVAL
The value argument exceeds {SEM_VALUE_MAX}.

ENOSPC
A resource required to initialize the semaphore has been exhausted, or the
limit on semaphores ({SEM_NSEMS_MAX}) has been reached.

EPERM
The process lacks appropriate privileges to initialize the semaphore.

The sem_init() function may fail if:

EMFILE
All file descriptors available to the process are currently open.

ENFILE
The maximum allowable number of files is currently open in the system.

EXAMPLES
None.

APPLICATION USAGE
None.

RATIONALE
None.

FUTURE DIRECTIONS
None.
NAME
sem_open — initialize and open a named semaphore

SYNOPSIS
#include <semaphore.h>

sem_t *sem_open(const char *name, int oflag, ...);

DESCRIPTION
The sem_open() function shall establish a connection between a named semaphore and a process.
A named semaphore may be implemented using a file descriptor. Following a call to sem_open() with
the semaphore name name, the process may reference the semaphore associated with name
using the address returned from the call. This semaphore can be used in subsequent calls to
sem_clockwait(), sem_close(), sem_post(), sem_timedwait(), sem_trywait(), and sem_wait(). The
semaphore remains usable by this process until the semaphore is closed by a successful call to
sem_close(), _exit(), or one of the exec functions.

The oflag argument controls whether the semaphore is created or merely accessed by the call to
sem_open(). The following flag bits may be set in oflag:

O_CREAT This flag is used to create a semaphore if it does not already exist. If O_CREAT is
set and the semaphore already exists, then O_CREAT has no effect, except as noted
under O_EXCL. Otherwise, sem_open() creates a named semaphore. The O_CREAT
flag requires a third and a fourth argument: mode, which is of type mode_t, and
value, which is of type unsigned. The semaphore is created with an initial value of
value. Valid initial values for semaphores are less than or equal to
{SEM_VALUE_MAX}.

The user ID of the semaphore shall be set to the effective user ID of the process.
The group ID of the semaphore shall be set to the effective group ID of the process;
however, if the name argument is visible in the file system, the group ID may be set
to the group ID of the containing directory. The permission bits of the semaphore
are set to the value of the mode argument except those set in the file mode creation
mask of the process. When bits in mode other than the file permission bits are
specified, the effect is unspecified.

After the semaphore named name has been created by sem_open() with the
O_CREAT flag, other processes can connect to the semaphore by calling
sem_open() with the same value of name.

O_EXCL If O_EXCL and O_CREAT are set, sem_open() fails if the semaphore name exists.
The check for the existence of the semaphore and the creation of the semaphore if it
does not exist are atomic with respect to other processes executing sem_open() with
O_EXCL and O_CREAT set. If O_EXCL is set and O_CREAT is not set, the effect is
undefined.

If flags other than O_CREAT and O_EXCL are specified in the oflag parameter, the
effect is unspecified.

The name argument points to a string naming a semaphore object. It is unspecified whether the
name appears in the file system and is visible to functions that take pathnames as arguments.
The name argument conforms to the construction rules for a pathname, except that the
interpretation of <slash> characters other than the leading <slash> character in name is
implementation-defined, and that the length limits for the name argument are implementation-
defined and need not be the same as the pathname limits {PATH_MAX} and {NAME_MAX}. If
name begins with the <slash> character, then processes calling sem_open() with the same value of
name shall refer to the same semaphore object, as long as that name has not been removed. If
NAME
sem_clockwait, sem_timedwait — lock a semaphore

SYNOPSIS
#include <semaphore.h>

int sem_clockwait(sem_t *restrict sem, clockid_t clock_id,
                  const struct timespec *restrict abstime);
int sem_timedwait(sem_t *restrict sem,
                  const struct timespec *restrict abstime);

DESCRIPTION
The sem_clockwait() and sem_timedwait() functions shall lock the semaphore referenced by sem
as in the sem_wait() function. However, if the semaphore cannot be locked without waiting for
another process or thread to unlock the semaphore by performing a sem_post() function, this
wait shall be terminated when the specified timeout expires.

The timeout shall expire when the absolute time specified by abstime passes, as measured by the
clock on which timeouts are based (that is, when the value of that clock equals or exceeds
abstime), or if the absolute time specified by abstime has already been passed at the time of the
call.

For sem_timedwait(), the timeout shall be based on the CLOCK_REALTIME clock. For
sem_clockwait(), the timeout shall be based on the clock specified by the clock_id argument. The
resolution of the timeout shall be the resolution of the clock on which it is based.
Implementations shall support passing CLOCK_REALTIME and CLOCK_MONOTONIC to
sem_clockwait() as the clock_id argument.

Under no circumstance shall the function fail with a timeout if the semaphore can be locked
immediately. The validity of the abstime need not be checked if the semaphore can be locked
immediately.

RETURN VALUE
The sem_clockwait() and sem_timedwait() functions shall return zero if the calling process
successfully performed the semaphore lock operation on the semaphore designated by sem. If
the call was unsuccessful, the state of the semaphore shall be unchanged, and the functions shall
return a value of −1 and set errno to indicate the error.

ERRORS
The sem_clockwait() and sem_timedwait() functions shall fail if:

[EINVAL] The process or thread would have blocked, and either the abstime parameter
specified a nanoseconds field value less than zero or greater than or equal to
1000 million, or the sem_clockwait() function was passed an invalid or
unsupported clock_id value.

[ETIMEDOUT] The semaphore could not be locked before the specified timeout expired.
The sem_clockwait() and sem_timedwait() functions may fail if:

[EDEADLK] A deadlock condition was detected.
[EINTR] A signal interrupted the function.
[EINVAL] The sem argument does not refer to a valid semaphore.
EXAMPLES

The program shown below operates on an unnamed semaphore. The program expects two command-line arguments. The first argument specifies a seconds value that is used to set an alarm timer to generate a SIGALRM signal. This handler performs a sem_post() to increment the semaphore that is being waited on in main() using sem_clockwait(). The second command-line argument specifies the length of the timeout, in seconds, for sem_clockwait().

```c
#include <unistd.h>
#include <stdio.h>
#include <stdlib.h>
#include <semaphore.h>
#include <time.h>
#include <assert.h>
#include <errno.h>
#include <signal.h>

sem_t sem;

static void handler(int sig)
{
    int sav_errno = errno;
    static const char info_msg[] = "sem_post() from handler\n";
    write(STDOUT_FILENO, info_msg, sizeof info_msg - 1);
    if (sem_post(&sem) == -1) {
        static const char err_msg[] = "sem_post() failed\n";
        write(STDERR_FILENO, err_msg, sizeof err_msg - 1);
        _exit(EXIT_FAILURE);
    }
    errno = sav_errno;
}

int main(int argc, char *argv[])
{
    struct sigaction sa;
    struct timespec ts;
    int s;
    if (argc != 3) {
        fprintf(stderr, "Usage: %s <alarm-secs> <wait-secs>\n", argv[0]);
        exit(EXIT_FAILURE);
    }
    if (sem_init(&sem, 0, 0) == -1) {
        perror("sem_init");
        exit(EXIT_FAILURE);
    }

    /* Establish SIGALRM handler; set alarm timer using argv[1] */
    sa.sa_handler = handler;
    sigemptyset(&sa.sa_mask);
    sa.sa_flags = 0;
    if (sigaction(SIGALRM, &sa, NULL) == -1) {
        perror("sigaction");
        exit(EXIT_FAILURE);
    }
    /* Establish SIGALRM handler; set alarm timer using argv[1] */
    sa.sa_handler = handler;
    sigemptyset(&sa.sa_mask);
    sa.sa_flags = 0;
    if (sigaction(SIGALRM, &sa, NULL) == -1) {
        perror("sigaction");
        exit(EXIT_FAILURE);
    }
}
```
sem_timedwait()

```
    perror("sigaction");
    exit(EXIT_FAILURE);

    alarm(atoi(argv[1]));

    /* Calculate relative interval as current time plus
     * number of seconds given argv[2] */
    if (clock_gettime(CLOCK_MONOTONIC, &ts) == -1) {
        perror("clock_gettime");
        exit(EXIT_FAILURE);
    }
    ts.tv_sec += atoi(argv[2]);
    printf("main() about to call sem_clockwait()\n");
    while ((s = sem_clockwait(&sem, CLOCK_MONOTONIC, &ts)) == -1 &&
        errno == EINTR)
        continue; /* Restart if interrupted by handler */
    /* Check what happened */
    if (s == -1) {
        if (errno == ETIMEDOUT)
            printf("sem_clockwait() timed out\n");
        else
            perror("sem_clockwait");
    } else
        printf("sem_clockwait() succeeded\n");
    exit((s == 0) ? EXIT_SUCCESS : EXIT_FAILURE);
```

APPLICATION USAGE
Applications using these functions may be subject to priority inversion, as discussed in XBD
Section 3.260 (on page 66).

RATIONALE
None.

FUTURE DIRECTIONS
None.

SEE ALSO
sem_post(), sem_trywait(), semctl(), semget(), semop(), time()
XBD Section 3.260 (on page 66), <semaphore.h>, <time.h>

CHANGE HISTORY
IEEE Std 1003.1-2001/Cor 2-2004, item XSH/TC2/D6/120 is applied, updating the ERRORS
section so that the [EINVAL] error becomes optional.

Issue 7
The sem_timedwait() function is moved from the Semaphores option to the Base.
Functionality relating to the Timers option is moved to the Base.
An example is added.
NAME

sig2str, str2sig — translate between signal names and numbers

SYNOPSIS

```
#include <signal.h>

int sig2str(int signum, char *str);
int str2sig(const char *restrict str, int *restrict pnum);
```

DESCRIPTION

The `sig2str()` function shall translate the signal number specified by `signum` to a signal name and shall store this string in the location specified by `str`. The application shall ensure that `str` points to a location that can store the string including the terminating null byte. The symbolic constant SIG2STR_MAX defined in `<signal.h>` gives the maximum number of bytes required.

If `signum` is equal to 0, the behavior is unspecified.

If `signum` is equal to one of the symbolic constants listed in the table of signal numbers in `<signal.h>`, the stored signal name shall be the name of the symbolic constant without the SIG prefix.

If `signum` is equal to SIGRTMIN or SIGRTMAX, the stored string shall be "RTMIN" or "RTMAX", respectively.

If `signum` is between SIGRTMIN+1 and (SIGRTMIN+SIGRTMAX)/2 inclusive, the stored string shall be of the form "RTMIN+n", where `n` is the shortest decimal representation of the value of `signum`−SIGRTMIN.

If `signum` is between (SIGRTMIN+SIGRTMAX)/2 + 1 and SIGRTMAX−1 inclusive, the stored string shall be either of the form "RTMIN+n" or of the form "RTMAX−m", where `n` is the shortest decimal representation of the value of `signum`−SIGRTMIN and `m` is the shortest decimal representation of the value of SIGRTMAX−`signum`.

If `signum` is a valid, supported signal number, is either less than SIGRTMIN or greater than SIGRTMAX, and is not equal to one of the symbolic constants listed in the table of signal numbers in `<signal.h>`, the stored string shall uniquely identify the signal number `signum` in an unspecified manner.

The `str2sig()` function shall translate the signal name in the string pointed to by `str` to a signal number and shall store this value in the location specified by `pnum`.

If `str` points to a string containing the name of one of the symbolic constants listed in the table of signal numbers in `<signal.h>`, without the SIG prefix, the stored signal number shall be equal to the value of the symbolic constant.

If `str` points to the string "RTMIN" or "RTMAX", the stored value shall be equal to SIGRTMIN or SIGRTMAX, respectively.

If `str` points to a string of the form "RTMIN+n", where `n` is a decimal representation of a number between 1 and SIGRTMAX−SIGRTMIN−1 inclusive, the stored value shall be equal to SIGRTMIN+n.

If `str` points to a string of the form "RTMAX−n", where `n` is a decimal representation of a number between 1 and SIGRTMAX−SIGRTMIN−1 inclusive, the stored value shall be equal to SIGRTMAX−`n`.

If `str` points to a string containing a decimal representation of a valid, supported signal number, the value stored in the location pointed to by `pnum` shall be equal to that number.
If `str` points to a string containing a decimal representation of the value 0 and the string was not returned by a previous successful call to `sig2str()` with a `signum` argument of 0, the behavior is unspecified.

If `str` points to a string returned by a previous successful call to `sig2str(signum, str)`, the value stored in the location pointed to by `pnum` shall be equal to `signum`.

If `str` points to a string that does not meet any of the above criteria, `str2sig()` shall store a value in the location pointed to by `pnum` if and only if it recognizes the string as an additional implementation-dependent form of signal name.

**RETURN VALUE**

If `signum` is a valid, supported signal number (that is, one for which `kill()` does not return −1 with `errno` set to [EINVAL]), the `sig2str()` function shall return 0; otherwise, if `signum` is not equal to 0, it shall return −1.

If `str2sig()` stores a value in the location pointed to by `pnum`, it shall return 0; otherwise, it shall return −1.

**ERRORS**

No errors are defined.

**EXAMPLES**

None.

**APPLICATION USAGE**

None.

**RATIONALE**

Historical versions of these functions translated a `signum` value 0 to "EXIT" (and vice versa), so that they could be used by the shell for the `trap` utility. When adding the functions to this standard, the standard developers felt that they should be aimed at more general-purpose use, and consequently requiring this behavior did not seem appropriate and so the behavior in this case has been made unspecified.

**FUTURE DIRECTIONS**

None.

**SEE ALSO**

`kill()`, `sigaction()`, `strsignal()`

**XBD `<signal.h>`**

**CHANGE HISTORY**

First released in Issue 8.
**NAME**

str2sig — translate between signal names and numbers

**SYNOPSIS**

```c
#include <signal.h>
int str2sig(const char *restrict str, int *restrict pnum);
```

**DESCRIPTION**

Refer to `sig2str()`.
NAME
strlcat, strlcpy — size-bounded string concatenation and copying

SYNOPSIS
CX
#include <string.h>

size_t strlcat(char *restrict dst, const char *restrict src, 
size_t dstsize);

size_t strlcpy(char *restrict dst, const char *restrict src, 
size_t dstsize);

DESCRIPTION
The strlcpy() and strlcat() functions copy and concatenate strings, stopping when either a NUL terminator in the source string is encountered or the specified full size of the destination buffer is reached. They NUL terminate the result if there is room. The application should ensure that room for the NUL terminator is included in dstsize.

The strlcpy() function shall copy not more than dstsize – 1 bytes from the string pointed to by src to the array pointed to by dst; a NUL byte in src and bytes that follow it shall not be copied. A terminating NUL byte shall be appended to the result, unless dstsize is 0. If copying takes place between objects that overlap, the behavior is undefined.

The strlcat() function shall append not more than dstsize – strlen(dst) – 1 bytes from the string pointed to by src to the end of the string pointed to by dst; a NUL byte in src and bytes that follow it shall not be appended. The initial byte of src shall overwrite the NUL byte at the end of dst. A terminating NUL byte shall be appended to the result, unless its location would be at or beyond dst + dstsize. If copying takes place between objects that overlap, the behavior is undefined.

The strlcpy() and strlcat() functions shall not change the setting of errno on valid input.

RETURN VALUE
Upon successful completion, the strlcpy() function shall return the length of the string pointed to by src; that is, the number of bytes in the string, not including the terminating NUL byte.

Upon successful completion, the strlcat() function shall return the initial length of the string pointed to by dst plus the length of the string pointed to by src.

No return values are reserved to indicate an error.

ERRORS
No errors are defined.

EXAMPLES
The following example detects truncation while combining a path prefix (including trailing <slash>) and a filename to produce a portable pathname:

```c
char *prefix, *filenam, pathnam[_POSIX_PATH_MAX];

if (strlcpy(pathnam, prefix, sizeof pathnam) >= sizeof pathnam ||
    strlcat(pathnam, filenam, sizeof pathnam) >= sizeof pathnam)
{
    // truncation occurred
    ...
}
```

This code ensures there is room for the NUL terminator by:
· Calling `strlcpy()` with a non-zero `dstsize` argument.
· Only calling `strlcat()` if the return value of `strlcpy()` indicated that truncation did not occur.

**APPLICATION USAGE**
The return value of the `strlcpy()` and `strlcat()` functions follows the same convention as `snprintf();` that is, they return the total length of the string they tried to create. If the return value is greater than or equal to `dstsize`, the output string has been truncated.

**RATIONALE**
None.

**FUTURE DIRECTIONS**
None.

**SEE ALSO**
`fprintf()`, `strlen()`, `strncat()`, `strncpy()`, `wcscat()`

**CHANGE HISTORY**
First released in Issue 8.
NAME
wcslcat, wcslcpy — size-bounded wide string concatenation and copying

SYNOPSIS
CX
#include <wchar.h>

size_t wcslcat(wchar_t *restrict dst, const wchar_t *restrict src, size_t dstsize);
size_t wcslcpy(wchar_t *restrict dst, const wchar_t *restrict src, size_t dstsize);

DESCRIPTION
The wcslcpy() and wcslcat() functions copy and concatenate wide strings, stopping when either a terminating null wide-character code in the source wide string is encountered or the specified full size (in wide-character codes) of the destination buffer is reached. They null terminate the result if there is room. The application should ensure that room for the terminating null wide-character code is included in dstsize.

The wcslcpy() function shall copy not more than dstsize – 1 wide-character codes from the wide string pointed to by src to the array pointed to by dst; a terminating null wide-character code in src and wide-character codes that follow it shall not be copied. A terminating null wide-character code shall be appended to the result, unless dstsize is 0. If copying takes place between objects that overlap, the behavior is undefined.

The wcslcat() function shall append not more than dstsize – wcslen(dst) – 1 wide-character codes from the wide string pointed to by src to the end of the wide string pointed to by dst; a terminating null wide-character code in src and wide-character codes that follow it shall not be appended. The initial wide-character code of src shall overwrite the null wide-character code at the end of dst. A terminating null wide-character code shall be appended to the result, unless its location would be at or beyond dst + dstsize. If copying takes place between objects that overlap, the behavior is undefined.

The wcslcpy() and wcslcat() functions shall not change the setting of errno on valid input.

RETURN VALUE
Upon successful completion, the wcslcpy() function shall return the length of the wide string pointed to by src; that is, the number of wide-character codes in the wide string, not including the terminating null wide-character code.

Upon successful completion, the wcslcat() function shall return the initial length of the wide string pointed to by dst plus the length of the wide string pointed to by src.

No return values are reserved to indicate an error.

ERRORS
No errors are defined.

EXAMPLES
None.

APPLICATION USAGE
The return value of the wcslcpy() and wcslcat() functions follows the same convention as snprintf(); that is, they return the total length (in wide-character codes) of the wide string they tried to create. If the return value is greater than or equal to dstsize, the output wide string has been truncated.
**wcsleat()**

*System Interfaces*

**RATIONALE**
None.

**FUTURE DIRECTIONS**
None.

**SEE ALSO**
fprintf(), strlcat(), wcslen(), wcsncat(), wcsncpy()
XBD <wchar.h>

**CHANGE HISTORY**
First released in Issue 8.
POSIX.1b is a software, source-level standard and most of the benefits of the alternate representation are enjoyed by hardware implementations of clocks and algorithms. It was felt that mandating this format for POSIX.1b clocks and timers would unnecessarily burden the application developer with writing, possibly non-portable, multiple precision arithmetic packages to perform conversion between binary fractions and integral units such as nanoseconds, milliseconds, and so on.

**Rationale for the Monotonic Clock**

For those applications that use time services to achieve realtime behavior, changing the value of the clock on which these services rely may cause erroneous timing behavior. For these applications, it is necessary to have a monotonic clock which cannot run backwards, and which has a maximum clock jump that is required to be documented by the implementation. Additionally, it is desirable (but not required by POSIX.1-202x) that the monotonic clock increases its value uniformly. This clock should not be affected by changes to the system time; for example, to synchronize the clock with an external source or to account for leap seconds. Such changes would cause errors in the measurement of time intervals for those time services that use the absolute value of the clock.

One could argue that by defining the behavior of time services when the value of a clock is changed, deterministic realtime behavior can be achieved. For example, one could specify that relative time services should be unaffected by changes in the value of a clock. However, there are time services that are based upon an absolute time, but that are essentially intended as relative time services. For example, `pthread_cond_timedwait()` uses an absolute time to allow it to wake up after the required interval despite spurious wakeups. Although sometimes the `pthread_cond_timedwait()` timeouts are absolute in nature, there are many occasions in which they are relative, and their absolute value is determined from the current time plus a relative time interval. In this latter case, if the clock changes while the thread is waiting, the wait interval will not be the expected length. If a `pthread_cond_timedwait()` function were created that would take a relative time, it would not solve the problem because to retain the intended “deadline” a thread would need to compensate for latency due to the spurious wakeup, and preemption between wakeup and the next wait.

The solution is to create a new monotonic clock, whose value does not change except for the regular ticking of the clock, and use this clock for implementing the various relative timeouts that appear in the different POSIX interfaces, as well as allow `pthread_cond_timedwait()` to choose this new clock for its timeout. A new `clock_nanosleep()` function is created to allow an application to take advantage of this newly defined clock. Notice that the monotonic clock may be implemented using the same hardware clock as the system clock.

Relative timeouts for `sigtimedwait()` and `aio_suspend()` have been redefined to use the monotonic clock, if present. The `alarm()` function has not been redefined, because the same effect but with better resolution can be achieved by creating a timer (for which the appropriate clock may be chosen).

The `pthread_cond_timedwait()` function has been treated in a different way, compared to other functions with absolute timeouts, because it is used to wait for an event, and thus it may have a deadline, while the other timeouts are generally used as an error recovery mechanism, and for them the use of the monotonic clock is not so important. Since the desired timeout for the `pthread_cond_timedwait()` function may either be a relative interval or an absolute time of day deadline, a new initialization attribute has been created for condition variables to specify the clock that is used for measuring the timeout in a call to `pthread_cond_timedwait()`. In this way, if a relative timeout is desired, the monotonic clock will be used; if an absolute deadline is required instead, the CLOCK_REALTIME or another appropriate clock may be used. For condition variables, this capability is also available by passing CLOCK_MONOTONIC to the
It was later found necessary to add variants of almost all interfaces that accept absolute timeouts that allow the clock to be specified. This is because, despite the claim in the previous paragraph, it is not possible to safely use a CLOCK_REALTIME absolute timeout even to prevent errors when the system clock is warped by a potentially large amount. A "safety timeout" of a minute on a call to pthread_mutex_timedlock() could actually mean that the call would return ETIMEDOUT early without acquiring the lock if the system clock is warped forwards immediately prior to or during the call. On the other hand, a short timeout could end up being arbitrarily long if the system clock is warped backwards immediately prior to or during the call. These problems are solved by the new clockwait and clocklock variants of the existing timedwait and timedlock functions. These variants accept an extra clockid_t parameter to indicate the clock to be used for the wait. The clock ID is passed rather than using attributes as previously for pthread_cond_timedwait() in order to allow the ISO/IEC 14882:2011 standard (C++11) and later to be implemented correctly. C++ requires that the clock to use for the wait is not known until the time of the wait call, so it cannot be supplied during creation. The new functions are pthread_cond_clockwait(), pthread_mutex_clocklock(), pthread_mutex_clockrdlock(), pthread_mutex_clockwrlock(), and sem_clockwait(). It is expected that mq_clockreceive() and mq_clocksend() functions will be added in a future version of this standard.

The nanosleep() function has not been modified with the introduction of the monotonic clock. Instead, a new clock_nanosleep() function has been created, in which the desired clock may be specified in the function call.

- History of Resolution Issues

  Due to the shift from relative to absolute timeouts in IEEE Std 1003.1d-1999, the amendments to the sem_timedwait(), pthread_mutex_timedlock(), mq_timedreceive(), and mq_timedsend() functions of that standard have been removed. Those amendments specified that CLOCK_MONOTONIC would be used for the (relative) timeouts if the Monotonic Clock option was supported.

  Having these functions continue to be tied solely to CLOCK_MONOTONIC would not work. Since the absolute value of a time value obtained from CLOCK_MONOTONIC is unspecified, under the absolute timeouts interface, applications would behave differently depending on whether the Monotonic Clock option was supported or not (because the absolute value of the clock would have different meanings in either case).

  Two options were considered:

  1. Leave the current behavior unchanged, which specifies the CLOCK_REALTIME clock for these (absolute) timeouts, to allow portability of applications between implementations supporting or not the Monotonic Clock option.

  2. Modify these functions in the way that pthread_cond_timedwait() was modified to allow a choice of clock, so that an application could use CLOCK_REALTIME when it is trying to achieve an absolute timeout and CLOCK_MONOTONIC when it is trying to achieve a relative timeout.

  It was decided that the features of CLOCK_MONOTONIC are not as critical to these functions as they are to pthread_cond_timedwait(). The pthread_cond_timedwait() function is given a relative timeout; the timeout may represent a deadline for an event. When these functions are given relative timeouts, the timeouts are typically for error recovery purposes and need not be so precise.

  Therefore, it was decided that these functions should be tied to CLOCK_REALTIME and
Supported Threads Functions

On POSIX-conforming systems, the following symbolic constants are always conforming:

_POSIX_READER_WRITER_LOCKS
_POSIX_THREADS

Therefore, the following threads functions are always supported:

- `pthread_atfork()`
- `pthread_attr_destroy()`
- `pthread_attr_getdetachstate()`
- `pthread_attr_getguardsize()`
- `pthread_attr_getschedparam()`
- `pthread_attr_init()`
- `pthread_attr_setdetachstate()`
- `pthread_attr_setguardsize()`
- `pthread_attr_setschedparam()`
- `pthread_cancel()`
- `pthread_cleanup_pop()`
- `pthread_cleanup_push()`
- `pthread_cond_broadcast()`
- `pthread_cond_clockwait()`
- `pthread_cond_destroy()`
- `pthread_cond_init()`
- `pthread_cond_signal()`
- `pthread_cond_timedwait()`
- `pthread_cond_wait()`
- `pthread_condattr_destroy()`
- `pthread_condattr_getpshared()`
- `pthread_condattr_init()`
- `pthread_condattr_setpshared()`
- `pthread_create()`
- `pthread_detach()`
- `pthread_equal()`
- `pthread_exit()`
- `pthread_getspecific()`
- `pthread_getspecific()`
- `pthread_setspecific()`
- `pthread_join()`
- `pthread_key_create()`
- `pthread_key_delete()`
- `pthread_key_delete()`
General Information

Rationale for System Interfaces

pthread_mutex_lock()
pthread_mutex_trylock()
pthread_mutex_unlock()

to take account of the new mutex attribute type and to specify behavior which was
declared as undefined in POSIX.1c. How a calling thread acquires or releases a mutex now
depends upon the mutex type attribute.

The type attribute can have the following values:

PTHREAD_MUTEX_NORMAL
Basic mutex with no specific error checking built in. Does not report a deadlock error.

PTHREAD_MUTEX_RECURSIVE
Allows any thread to recursively lock a mutex. The mutex must be unlocked an equal
number of times to release the mutex.

PTHREAD_MUTEX_ERRORCHECK
Detects and reports simple usage errors; that is, an attempt to unlock a mutex that is
not locked by the calling thread or that is not locked at all, or an attempt to relock a
mutex the thread already owns.

PTHREAD_MUTEX_DEFAULT
The default mutex type. May be mapped to any of the above mutex types or may be
an implementation-defined type.

Normal mutexes do not detect deadlock conditions; for example, a thread will hang if it
tries to relock a normal mutex that it already owns. Attempting to unlock a mutex locked
by another thread, or unlocking an unlocked mutex, results in undefined behavior. Normal
mutexes will usually be the fastest type of mutex available on a platform but provide the
least error checking.

Recursive mutexes are useful for converting old code where it is difficult to establish clear
boundaries of synchronization. A thread can relock a recursive mutex without first
unlocking it. The relocking deadlock which can occur with normal mutexes cannot occur
with this type of mutex. However, multiple locks of a recursive mutex require the same
number of unlocks to release the mutex before another thread can acquire the mutex.
Furthermore, this type of mutex maintains the concept of an owner. Thus, a thread
attempting to unlock a recursive mutex which another thread has locked returns with an
error. A thread attempting to unlock a recursive mutex that is not locked returns with an
error. Never use a recursive mutex with condition variables because the implicit unlock
performed by pthread_cond_clockwait(), pthread_cond_timedwait(), or pthread_cond_wait() -
will not actually release the mutex if it had been locked multiple times.

Errorcheck mutexes provide error checking and are useful primarily as a debugging aid. A
thread attempting to relock an errorcheck mutex without first unlocking it returns with an
error. Again, this type of mutex maintains the concept of an owner. Thus, a thread
attempting to unlock an errorcheck mutex which another thread has locked returns with
an error. A thread attempting to unlock an errorcheck mutex that is not locked also returns
with an error. It should be noted that errorcheck mutexes will almost always be much
slower than normal mutexes due to the extra state checks performed.

The default mutex type provides implementation-defined error checking. The default
mutex may be mapped to one of the other defined types or may be something entirely
different. This enables each vendor to provide the mutex semantics which the vendor feels
will be most useful to their target users. Most vendors will probably choose to make
normal mutexes the default so as to give applications the benefit of the fastest type of
Unsatisfied Requirements

D.2.5 Bounded (Realtime) Response

The realtime signal functions `sigqueue()`, `sigtimedwait()`, and `sigwaitinfo()` provide queued signals and the prioritization of the handling of signals.

The SCHED_FIFO, SCHED_SPORADIC, and SCHED_RR scheduling policies provide control over processor allocation.

The semaphore functions `sem_clockwait()`, `sem_close()`, `sem_destroy()`, `sem_getvalue()`, `sem_init()`, `sem_open()`, `sem_post()`, `sem_timedwait()`, `sem_trywait()`, `sem_unlink()`, and `sem_wait()` provide high-performance synchronization.

The memory management functions provide memory locking for control of memory allocation, file mapping for high performance, and shared memory for high-performance interprocess communication. The Message Passing option provides for interprocess communication without being dependent on shared memory.

The timers functions `clock_getres()`, `clock_gettime()`, `clock_settime()`, `nanosleep()`, `timer_create()`, `timer_delete()`, `timer_getoverrun()`, `timer_gettime()`, and `timer_settime()` provide functionality to manipulate clocks and timers and include a high resolution function called `nanosleep()` with a finer resolution than the `sleep()` function.

The timeout functions — `pthread_mutex_clocklock()`, `pthread_mutex_timedlock()`, `pthread_rwlock_clockrdlock()`, `pthread_rwlock_clockwrlock()`, `pthread_rwlock_timedrdlock()`, `pthread_rwlock_timedwrlock()`, `sem_clockwait()`, and `sem_timedwait()` — the Typed Memory + Objects option and the Monotonic Clock option provide further facilities for applications to use to obtain predictable bounded response.

D.2.6 Operating System-Dependent Profile

POSIX.1-202x makes no distinction between text and binary files. The values of EXIT_SUCCESS and EXIT_FAILURE are further defined.

Unsatisfied Requirements

None known, but the ISO C standard may contain some additional options that could be specified.

D.2.7 I/O Interaction

POSIX.1-202x defines how each of the ISO C standard `stdio` functions interact with the POSIX.1 operations, typically specifying the behavior in terms of POSIX.1 operations.
POSIX_C_LANG_SUPPORT: General ISO C Library

abs(), asctime(), atol(), atoll(), bsearch(), calloc(), ct ime(), diff time(), div(),
feclearexcept(), fegetenv(), fegetexpflag(), fegetround(), feholdexcept(), feraiseexcept(),
fsel etenv(), fet setexpflag(), fetsetround(), fetsetexcept(), fesetupdateenv(), free(), gtime(),
imax(abs), imaxdiv(), iminum(), isalpha(), isblank(), iscntrl(), isdigit(), isgraph(), islower(),
isprint(), ispunct(), isspace(), isupper(), isxdigit(), labs(), ldio(), labs(), lldio(), localeconv(),
localtime(), malloc(), memchr(), memcmp(), memcpy(), memmove(), memset(), mktime(),
qsort(), rand(), realloc(), setlocale(), snprintf(), sprintf(), srand(), sscanf(), strcat(), strchr(),
strcmp(), strcoll(), strcspn(), strerror(), strftime(), strlen(), strncat(), strncmp(),
strncpy(), strpbrk(), strrev(), strspn(), strlen(), strtof(), strtold(), strtof(), strtoimax(),
strtok(), strtof(), strtof(), strtof(), strtof(), strtof(), strtof(), strtof(),
tzname(), tcset(), va_arg(), va_copy(), va_end(), va_start(), vsnprintf(), vsprintf(),
wcscanf() +

POSIX_C_LANG_SUPPORT_R: Thread-Safe General ISO C Library

asctime_r(), ctime_r(), gtime_r(), localtime_r(), qsort_r(), strerror_r(), strtof_r() +

POSIX_C_LANG_WIDE_CHAR: Wide-Character ISO C Library

btowc(), iswalnum(), iswalpha(), iswblank(), iswcntrl(), iswctype(), iswdigit(), iswgraph(),
iswlower(), iswprint(), iswpunct(), iswspace(), iswupper(), iswxdigit(), mblen(), mbset(),
mbrtowc(), mbstowcs(), mbstowc(), mbtowc(), swprintf(), wcs canf(), towtrans(),
towlower(), towupper(), vsprintf(), vsnscanf(), wcrtomb(), wcs cat(), wcscat(), wcscmp(),
wcscoll(), wcscpy(), wcscspn(), wcserror(), wcsftime(), wcslen(), wcsnchap(), wcsncpy(),
wcsncpy(), wcsrchr(), wcsrtombs(), wcsstr(), wcsto сф(), wcstol(), wcsconsumer(),
wcstok(), wcstol(), wcstold(), wcstold(), wcstombs(), wcstoul(), wcstoumax(),
wcxfm(), wcscat(), wcscat(), wcstrans(), wctype(), wmemchr(), wmemcmp(), wmemcpy(),
wmemmove(), wmemset() +

POSIX_C_LANG_WIDE_CHAR_EXT: Extended Wide-Character ISO C Library

mbstowces(), wcpcpy(), wcpcpy(), wcsvcasecmp(), wcscat(), wcsvcat(), wcsvcpy(),
wcsvcasecmp(), wcsvlen(), wcsvrtoms() +

POSIX_C_LIB_EXT: General C Library Extension

ftime(), getentropy(), getopt(), getsubopt(), memmem(), optarg(), optarg, optind(), optopt,
reallocarray(), s tpcpy(), stpcpy(), strcasecmp(), strdup(), strfmon(), strlcat(), strlcpy(),
strtoken(), strndup(), strnlen() +

POSIX_CLOCK_SELECTION: Clock Selection

clock_gettime(), pthread_condattr_getclock(), pthread_condattr_setclock() +

POSIX_DEVICE_IO: Device Input and Output

FD_CLR(), FD_ISSET(), FD_SET(), FD_ZERO(), clearerr(), close(), clese(), fdopen(), feof(),
fferror(), fflush(), fgetct(), fgets(), fileno(), fopen(), fprintf(), fputc(), fgets(), fread(), freopen(),
fs canf(), fwrite(), getchar(), open(), perror(), poll(), ppoll(), printf(), pread(), pselect(),
putc(), putchar(), puts(), putwrit(), read(), scanf(), select(), setbuf(), setvbuf(), stidr(), stdin,
stodout(), ungetc(), vsprintf(), vsscanf(), vsprintf(), vsscanf(), write() +

POSIX_DEVICE_IO_EXT: Extended Device Input and Output

dprintf(), fnmopen(), open_memstream(), vfprintf() +

POSIX_DEVICE_SPECIFIC: General Terminal

cfgetispeed(), cfgetospeed(), cfsetispeed(), cfsetospeed(), cf termid(), isatty(), tcdrain(), t cflow(),
tcflush(), tcgetattr(), tcgetwinsize(), tcsetbreak(), tcsetattr(), tcsetwinsize(), ttyname()
POSIX_DEVICE_SPECIFIC_R: Thread-Safe General Terminal

ttyname_r()

POSIX_DYNAMIC_LINKING: Dynamic Linking
dladdr(), dlclose(), dlerror(), dlopen(), dsym()

POSIX_FD_MGMT: File Descriptor Management
dup(), dup2(), dup3(), fcntl(), fgetpos(), fseek(), fseeko(), fsetpos(), ftell(), ftello(), ftruncate(), lseek(), rewind()

POSIX_FIFO: FIFO
mkfifo()

POSIX_FIFO_FD: FIFO File Descriptor Routines
mkfifoat(), mknodat()

POSIX_FILE_ATTRIBUTES: File Attributes
chmod(), chown(), fchmod(), fchown(), umask()

POSIX_FILE_ATTRIBUTES_FD: File Attributes File Descriptor Routines
fchmodat(), fchownat()

POSIX_FILE_LOCKING: Thread-Safe Stdio Locking
flockfile(), ftrylockfile(), funlockfile(), getc_unlocked(), getchar_unlocked(), putc_unlocked(), putchar_unlocked()

POSIX_FILE_SYSTEM: File System
access(), chdir(), closedir(), creat(), fchdir(), fpathconf(), fstat(), fstatvfs(), getcwdd(), link(), mkdir(), mkostemp(), mkstemp(), opendir(), pathconf(), posix_getdents(), readdir(), remove(), rename(), rewinddir(), rmdir(), stat(), statvfs(), tmpfile(), tmpnam(), truncate(), unlink()

POSIX_FILE_SYSTEM_EXT: File System Extensions
alphasort(), dirfd(), getdelim(), getline(), mkdtemp(), scandir()

POSIX_FILE_SYSTEM_FD: File System File Descriptor Routines
faccessat(), fdopendir(), fstatat(), linkat(), mkdirat(), openat(), renameat(), unlinkat(), utimensat()

POSIX_FILE_SYSTEM_GLOB: File System Glob Expansion
glob(), globfree()

POSIX_FILE_SYSTEM_R: Thread-Safe File System
readdir_r()

POSIX_I18N: Internationalization
catclose(), catgets(), catopen(), iconv(), iconv_close(), iconv_open(), nl_langinfo()

POSIX_JOB_CONTROL: Job Control
setpgid(), tcgetpgrp(), tcsetpgrp(), tcgetsid()

POSIX_MAPPED_FILES: Memory Mapped Files
mmap(), munmap()

POSIX_MEMORY_PROTECTION: Memory Protection
mprotect()

POSIX_MULTI_CONCURRENT_LOCALES: Multiple Concurrent Locales
duplocale(), freelocale(), getlocalename_l(), isalnum_l(), isalpha_l(), isblank_l(), iscntrl_l(), isdigit_l(), isgraph_l(), islower_l(), isprint_l(), ispunct_l(), isspace_l(), isupper_l(), iswalnum_l(), iswalpha_l(), iswblank_l(), iswcntrl_l(), iswctype_l(), iswdigit_l(), iswgraph_l(), iswlower_l(), iswprint_l(), iswpunct_l(), iswspace_l(), iswupper_l(), isxdigit_l(), isxdigit_l(),
POSIX_MULTI_PROCESS: Multiple Processes

POSIX_MULTI_PROCESS_FD: Multiple Processes File Descriptor Routines

POSIX_NETWORKING: Networking

POSIX_ROBUST_MUTEXES: Robust Mutexes

POSIX_REALTIME_SIGNALS: Realtime Signals

POSIX_REGEXP: Regular Expressions

POSIX_RW_LOCKS: Reader Writer Locks

POSIX_SEMAPHORES: Semaphores

POSIX_SHELL_FUNC: Shell and Utilities

POSIX_SIGNAL_JUMP: Signal Jump Functions

POSIX_SIGNALS: Signals

POSIX_SIGNALS_EXT: Extended Signals
POSIX_SINGLE_PROCESS: Single Process
- `conffstr()`, `environ`, `errno`, `getenv()`, `setenv()`, `sysconf()`, `uname()`, `unsetenv()`

POSIX_SPIN_LOCKS: Spin Locks
- `pthread_spin_destroy()`, `pthread_spin_init()`, `pthread_spin_lock()`, `pthread_spin_trylock()`, `pthread_spin_unlock()`

POSIX_SYMBOLIC_LINKS: Symbolic Links
- `lchown()`, `lstat()`, `readlink()`, `symlink()`

POSIX_SYMBOLIC_LINKS_FD: Symbolic Links File Descriptor Routines
- `readlinkat()`, `symlinkat()`

POSIX_SYSTEM_DATABASE: System Database
- `getgrgid()`, `getgrnam()`, `getpwnam()`, `getpwuid()`

POSIX_SYSTEM_DATABASE_R: Thread-Safe System Database
- `getgrgid_r()`, `getgrnam_r()`, `getpwnam_r()`, `getpwuid_r()`

POSIX_THREADS_BASE: Base Threads
- `pthread_atfork()`, `pthread_attr_destroy()`, `pthread_attr_getdetachstate()`, `pthread_attr_getschedparam()`, `pthread_attr_init()`, `pthread_attr_setdetachstate()`,
- `pthread_attr_setschedparam()`, `pthread_cancel()`, `pthread_cleanup_pop()`, `pthread_cleanup_push()`,
- `pthread_cond_broadcast()`, `pthread_cond_clockwait()`, `pthread_cond_destroy()`,
- `pthread_cond_init()`, `pthread_cond_signal()`, `pthread_cond_timedwait()`, `pthread_cond_wait()`,
- `pthread_condattr_destroy()`, `pthread_condattr_init()`, `pthread_condattr_setattr()`,
- `pthread_equal()`, `pthread_exit()`, `pthread_getspecific()`, `pthread_join()`, `pthread_key_create()`,
- `pthread_key_delete()`, `pthread_kill()`, `pthread_mutex_clocklock()`, `pthread_mutex_destroy()`,
- `pthread_mutex_init()`, `pthread_mutex_lock()`, `pthread_mutex_timedlock()`,
- `pthread_mutexattr_destroy()`, `pthread_mutexattr_init()`

POSIX_THREADS_EXT: Extended Threads
- `pthread_attr_getguardsize()`, `pthread_attr_setguardsize()`,
- `pthread_attr_getsettype()`, `pthread_attr_setsettype()`,

POSIX_TIMERS: Timers
- `clock_getres()`, `clock_gettime()`, `clock_settime()`, `nanosleep()`,
- `timer_create()`, `timer_delete()`, `timer_getoverrun()`, `timer_gettime()`, `timer_settime()`

POSIX_USER_GROUPS: User and Group
- `getgname()`, `getuid()`, `getgid()`, `getgroups()`, `getlogin()`, `getuid()`, `setegid()`, `seteuid()`, `setgid()`, `setgroup()`

POSIX_USER_GROUPS_R: Thread-Safe User and Group
- `getgname_r()`, `getuid_r()`

POSIX_WIDE_CHAR_DEVICE_IO: Device Input and Output
- `fgetwc()`, `fgetws()`, `putwc()`, `putwss()`, `fwide()`, `fwprintf()`, `fscanf()`, `getwc()`, `getwchar()`,
- `putwc()`, `putwss()`, `ungetwc()`, `vwprintf()`, `vscanf()`, `vscanf()`

XSI_C_LANG_SUPPORT: XSI General C Library
- `a64l()`, `daylight()`, `drand48()`, `erand48()`, `ffs()`, `ffsll()`, `getdate()`, `hcreate()`, `hdestroy()`,
- `hsrach()`, `initstate()`, `insq()`, `jrand48()`, `l64a()`, `lcng48()`, `lfind()`, `lrand48()`, `lsearch()`,
- `memccpy()`, `mrand48()`, `nrand48()`, `random()`, `remque()`, `seed48()`, `setstate()`, `signgam`,

11. The `lchown()` function also depends on POSIX_FILE_ATTRIBUTES.