

NAME

kqueue, **kevent** - kernel event notification mechanism

LIBRARY

Standard C Library (libc, -lc)

SYNOPSIS

```
#include <sys/event.h>
```

int

```
kqueue(void);
```

int

```
kqueueex(u_int flags);
```

int

```
kevent(int kq, const struct kevent *changelist, int nchanges, struct kevent *eventlist, int nevents,  
const struct timespec *timeout);
```

```
EV_SET(kev, ident, filter, flags, fflags, data, udata);
```

DESCRIPTION

The **kqueue**() system call provides a generic method of notifying the user when an event happens or a condition holds, based on the results of small pieces of kernel code termed filters. A kevent is identified by the (ident, filter) pair; there may only be one unique kevent per kqueue.

The filter is executed upon the initial registration of a kevent in order to detect whether a preexisting condition is present, and is also executed whenever an event is passed to the filter for evaluation. If the filter determines that the condition should be reported, then the kevent is placed on the kqueue for the user to retrieve.

The filter is also run when the user attempts to retrieve the kevent from the kqueue. If the filter indicates that the condition that triggered the event no longer holds, the kevent is removed from the kqueue and is not returned.

Multiple events which trigger the filter do not result in multiple kevents being placed on the kqueue; instead, the filter will aggregate the events into a single struct kevent. Calling **close**() on a file descriptor will remove any kevents that reference the descriptor.

The **kqueue**() system call creates a new kernel event queue and returns a descriptor. The queue is not

inherited by a child created with `fork(2)`. However, if `rfork(2)` is called without the `RFFDG` flag, then the descriptor table is shared, which will allow sharing of the `kqueue` between two processes.

The `kqueuex()` system call also creates a new kernel event queue, and additionally takes the *flags* argument, which is a bitwise-inclusive OR of the following flags:

KQUEUE_CLOEXEC The returned file descriptor is automatically closed on `execve(2)`. The ‘`fd = kqueue()`’ call is equivalent to ‘`fd = kqueuex(0)`’.

For compatibility with NetBSD, the `kqueue1()` function is provided, which accepts the `O_CLOEXEC` flag with the expected semantic.

The `kevent()` system call is used to register events with the queue, and return any pending events to the user. The *changelist* argument is a pointer to an array of *kevent* structures, as defined in `<sys/event.h>`. All changes contained in the *changelist* are applied before any pending events are read from the queue. The *nchanges* argument gives the size of *changelist*. The *eventlist* argument is a pointer to an array of *kevent* structures. The *nevents* argument determines the size of *eventlist*. When *nevents* is zero, `kevent()` will return immediately even if there is a *timeout* specified unlike `select(2)`. If *timeout* is a non-NULL pointer, it specifies a maximum interval to wait for an event, which will be interpreted as a struct *timespec*. If *timeout* is a NULL pointer, `kevent()` waits indefinitely. To effect a poll, the *timeout* argument should be non-NULL, pointing to a zero-valued *timespec* structure. The same array may be used for the *changelist* and *eventlist*.

The `EV_SET()` macro is provided for ease of initializing a *kevent* structure.

The *kevent* structure is defined as:

```
struct kevent {
    uintptr_t ident; /* identifier for this event */
    short filter; /* filter for event */
    u_short flags; /* action flags for kqueue */
    u_int fflags; /* filter flag value */
    int64_t data; /* filter data value */
    void *udata; /* opaque user data identifier */
    uint64_t ext[4]; /* extensions */
};
```

The fields of *struct kevent* are:

ident Value used to identify this event. The exact interpretation is determined by the attached filter,

but often is a file descriptor.

- filter* Identifies the kernel filter used to process this event. The pre-defined system filters are described below.
- flags* Actions to perform on the event.
- fflags* Filter-specific flags.
- data* Filter-specific data value.
- udata* Opaque user-defined value passed through the kernel unchanged.
- ext* Extended data passed to and from kernel. The *ext[0]* and *ext[1]* members use is defined by the filter. If the filter does not use them, the members are copied unchanged. The *ext[2]* and *ext[3]* members are always passed through the kernel as-is, making additional context available to application.

The *flags* field can contain the following values:

- EV_ADD** Adds the event to the kqueue. Re-adding an existing event will modify the parameters of the original event, and not result in a duplicate entry. Adding an event automatically enables it, unless overridden by the **EV_DISABLE** flag.
- EV_ENABLE** Permit **kevent()** to return the event if it is triggered.
- EV_DISABLE** Disable the event so **kevent()** will not return it. The filter itself is not disabled.
- EV_DISPATCH** Disable the event source immediately after delivery of an event. See **EV_DISABLE** above.
- EV_DELETE** Removes the event from the kqueue. Events which are attached to file descriptors are automatically deleted on the last close of the descriptor.
- EV_RECEIPT** This flag is useful for making bulk changes to a kqueue without draining any pending events. When passed as input, it forces **EV_ERROR** to always be returned. When a filter is successfully added the *data* field will be zero. Note that if this flag is encountered and there is no remaining space in *eventlist* to hold the **EV_ERROR** event, then subsequent changes will not get processed.

- EV_ONESHOT** Causes the event to return only the first occurrence of the filter being triggered. After the user retrieves the event from the kqueue, it is deleted.
- EV_CLEAR** After the event is retrieved by the user, its state is reset. This is useful for filters which report state transitions instead of the current state. Note that some filters may automatically set this flag internally.
- EV_EOF** Filters may set this flag to indicate filter-specific EOF condition.
- EV_ERROR** See *RETURN VALUES* below.
- EV_KEEPUADATA**
Causes **kevent()** to leave unchanged any *udata* associated with an existing event. This allows other aspects of the event to be modified without requiring the caller to know the *udata* value presently associated. This is especially useful with **NOTE_TRIGGER** or flags like **EV_ENABLE**. This flag may not be used with **EV_ADD**.

The predefined system filters are listed below. Arguments may be passed to and from the filter via the *fflags* and *data* fields in the kevent structure.

- EVFILT_READ** Takes a descriptor as the identifier, and returns whenever there is data available to read. The behavior of the filter is slightly different depending on the descriptor type.

Sockets

Sockets which have previously been passed to **listen(2)** return when there is an incoming connection pending. *data* contains the size of the listen backlog.

Other socket descriptors return when there is data to be read, subject to the **SO_RCVLOWAT** value of the socket buffer. This may be overridden with a per-filter low water mark at the time the filter is added by setting the **NOTE_LOWAT** flag in *fflags*, and specifying the new low water mark in *data*. On return, *data* contains the number of bytes of protocol data available to read.

If the read direction of the socket has shutdown, then the filter also sets **EV_EOF** in *fflags*, and returns the socket error (if any) in *fflags*. It is possible for EOF to be returned (indicating the connection is gone) while there is still data pending in the socket buffer.

Vnodes

Returns when the file pointer is not at the end of file. *data* contains the offset from current position to end of file, and may be negative.

This behavior is different from `poll(2)`, where read events are triggered for regular files unconditionally. This event can be triggered unconditionally by setting the `NOTE_FILE_POLL` flag in *fflags*.

Fifos, Pipes

Returns when there is data to read; *data* contains the number of bytes available.

When the last writer disconnects, the filter will set `EV_EOF` in *flags*. This will be cleared by the filter when a new writer connects, at which point the filter will resume waiting for data to become available before returning.

BPF devices

Returns when the BPF buffer is full, the BPF timeout has expired, or when the BPF has "immediate mode" enabled and there is any data to read; *data* contains the number of bytes available.

Eventfds

Returns when the counter is greater than 0; *data* contains the counter value, which must be cast to *uint64_t*.

Kqueues

Returns when pending events are present on the queue; *data* contains the number of events available.

EVFILT_WRITE

Takes a descriptor as the identifier, and returns whenever it is possible to write to the descriptor. For sockets, pipes and fifos, *data* will contain the amount of space remaining in the write buffer. The filter will set `EV_EOF` when the reader disconnects, and for the fifo case, this will be cleared when a new reader connects. Note that this filter is not supported for vnodes.

For sockets, the low water mark and socket error handling is identical to the `EVFILT_READ` case.

For eventfds, *data* will contain the maximum value that can be added to the

counter without blocking.

For BPF devices, when the descriptor is attached to an interface the filter always indicates that it is possible to write and *data* will contain the MTU size of the underlying interface.

EVFILT_EMPTY

Takes a descriptor as the identifier, and returns whenever there is no remaining data in the write buffer.

EVFILT_AIO

Events for this filter are not registered with **kevent()** directly but are registered via the *aio_sigevent* member of an asynchronous I/O request when it is scheduled via an asynchronous I/O system call such as **aio_read()**. The filter returns under the same conditions as **aio_error()**. For more details on this filter see **sigevent(3)** and **aio(4)**.

EVFILT_VNODE

Takes a file descriptor as the identifier and the events to watch for in *fflags*, and returns when one or more of the requested events occurs on the descriptor. The events to monitor are:

NOTE_ATTRIB

The file referenced by the descriptor had its attributes changed.

NOTE_CLOSE

A file descriptor referencing the monitored file, was closed. The closed file descriptor did not have write access.

NOTE_CLOSE_WRITE

A file descriptor referencing the monitored file, was closed. The closed file descriptor had write access.

This note, as well as NOTE_CLOSE, are not activated when files are closed forcibly by **unmount(2)** or **revoke(2)**. Instead, NOTE_REVOKE is sent for such events.

NOTE_DELETE

The **unlink()** system call was called on the file referenced by the descriptor.

NOTE_EXTEND

For regular file, the file referenced by the descriptor was extended.

For directory, reports that a directory entry was added or removed, as the result of rename operation. The NOTE_EXTEND event is not reported when a name is changed inside the directory.

NOTE_LINK	The link count on the file changed. In particular, the NOTE_LINK event is reported if a subdirectory was created or deleted inside the directory referenced by the descriptor.
NOTE_OPEN	The file referenced by the descriptor was opened.
NOTE_READ	A read occurred on the file referenced by the descriptor.
NOTE_RENAME	The file referenced by the descriptor was renamed.
NOTE_REVOKE	Access to the file was revoked via revoke(2) or the underlying file system was unmounted.
NOTE_WRITE	A write occurred on the file referenced by the descriptor.

On return, *fflags* contains the events which triggered the filter.

EVFILT_PROC

Takes the process ID to monitor as the identifier and the events to watch for in *fflags*, and returns when the process performs one or more of the requested events. If a process can normally see another process, it can attach an event to it. The events to monitor are:

NOTE_EXIT	The process has exited. The exit status will be stored in <i>data</i> in the same format as the status returned by wait(2).
NOTE_FORK	The process has called fork() .
NOTE_EXEC	The process has executed a new process via

`execve(2)` or a similar call.

NOTE_TRACK Follow a process across **fork()** calls. The parent process registers a new kevent to monitor the child process using the same *fflags* as the original event. The child process will signal an event with **NOTE_CHILD** set in *fflags* and the parent PID in *data*.

If the parent process fails to register a new kevent (usually due to resource limitations), it will signal an event with **NOTE_TRACKERR** set in *fflags*, and the child process will not signal a **NOTE_CHILD** event.

On return, *fflags* contains the events which triggered the filter.

EVFILT_PROCDESC Takes the process descriptor created by `pdfork(2)` to monitor as the identifier and the events to watch for in *fflags*, and returns when the associated process performs one or more of the requested events. The events to monitor are:

NOTE_EXIT The process has exited. The exit status will be stored in *data*.

On return, *fflags* contains the events which triggered the filter.

EVFILT_SIGNAL Takes the signal number to monitor as the identifier and returns when the given signal is delivered to the process. This coexists with the **signal()** and **sigaction()** facilities, and has a lower precedence. The filter will record all attempts to deliver a signal to a process, even if the signal has been marked as **SIG_IGN**, except for the **SIGCHLD** signal, which, if ignored, will not be recorded by the filter. Event notification happens after normal signal delivery processing. *data* returns the number of times the signal has occurred since the last call to **kevent()**. This filter automatically sets the **EV_CLEAR** flag internally.

EVFILT_TIMER Establishes an arbitrary timer identified by *ident*. When adding a timer, *data* specifies the moment to fire the timer (for **NOTE_ABSTIME**) or the timeout period. The timer will be periodic unless **EV_ONESHOT** or **NOTE_ABSTIME** is specified. On return, *data* contains the number of

times the timeout has expired since the last call to **kevent()**. For non-monotonic timers, this filter automatically sets the `EV_CLEAR` flag internally.

The filter accepts the following flags in the *fflags* argument:

<code>NOTE_SECONDS</code>	<i>data</i> is in seconds.
<code>NOTE_MSECONDS</code>	<i>data</i> is in milliseconds.
<code>NOTE_USECONDS</code>	<i>data</i> is in microseconds.
<code>NOTE_NSECONDS</code>	<i>data</i> is in nanoseconds.
<code>NOTE_ABSTIME</code>	The specified expiration time is absolute.

If *fflags* is not set, the default is milliseconds. On return, *fflags* contains the events which triggered the filter.

Periodic timers with a specified timeout of 0 will be silently adjusted to timeout after 1 of the time units specified by the requested precision in *fflags*. If an absolute time is specified that has already passed, then it is treated as if the current time were specified and the event will fire as soon as possible.

If an existing timer is re-added, the existing timer will be effectively canceled (throwing away any undelivered record of previous timer expiration) and re-started using the new parameters contained in *data* and *fflags*.

There is a system wide limit on the number of timers which is controlled by the *kern.kq_calloutmax* sysctl.

EVFILT_USER

Establishes a user event identified by *ident* which is not associated with any kernel mechanism but is triggered by user level code. The lower 24 bits of the *fflags* may be used for user defined flags and manipulated using the following:

<code>NOTE_FFNOP</code>	Ignore the input <i>fflags</i> .
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NOTE_FFAND	Bitwise AND <i>fflags</i> .
NOTE_FFOR	Bitwise OR <i>fflags</i> .
NOTE_FFCOPY	Copy <i>fflags</i> .
NOTE_FFCTRLMASK	Control mask for <i>fflags</i> .
NOTE_FFLAGSMASK	User defined flag mask for <i>fflags</i> .

A user event is triggered for output with the following:

NOTE_TRIGGER	Cause the event to be triggered.
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On return, *fflags* contains the users defined flags in the lower 24 bits.

CANCELLATION BEHAVIOUR

If *nevents* is non-zero, i.e., the function is potentially blocking, the call is a cancellation point. Otherwise, i.e., if *nevents* is zero, the call is not cancellable. Cancellation can only occur before any changes are made to the *kqueue*, or when the call was blocked and no changes to the queue were requested.

RETURN VALUES

The **kqueue()** system call creates a new kernel event queue and returns a file descriptor. If there was an error creating the kernel event queue, a value of -1 is returned and *errno* set.

The **kevent()** system call returns the number of events placed in the *eventlist*, up to the value given by *nevents*. If an error occurs while processing an element of the *changelist* and there is enough room in the *eventlist*, then the event will be placed in the *eventlist* with *EV_ERROR* set in *flags* and the system error in *data*. Otherwise, -1 will be returned, and *errno* will be set to indicate the error condition. If the time limit expires, then **kevent()** returns 0.

EXAMPLES

```
#include <sys/event.h>
#include <err.h>
#include <fcntl.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
```

```
int
main(int argc, char **argv)
{
    struct kevent event; /* Event we want to monitor */
    struct kevent tevent; /* Event triggered */
    int kq, fd, ret;

    if (argc != 2)
        err(EXIT_FAILURE, "Usage: %s path\n", argv[0]);
    fd = open(argv[1], O_RDONLY);
    if (fd == -1)
        err(EXIT_FAILURE, "Failed to open '%s'", argv[1]);

    /* Create kqueue. */
    kq = kqueue();
    if (kq == -1)
        err(EXIT_FAILURE, "kqueue() failed");

    /* Initialize kevent structure. */
    EV_SET(&event, fd, EVFILT_VNODE, EV_ADD | EV_CLEAR, NOTE_WRITE,
          0, NULL);
    /* Attach event to the kqueue. */
    ret = kevent(kq, &event, 1, NULL, 0, NULL);
    if (ret == -1)
        err(EXIT_FAILURE, "kevent register");

    for (;;) {
        /* Sleep until something happens. */
        ret = kevent(kq, NULL, 0, &tevent, 1, NULL);
        if (ret == -1) {
            err(EXIT_FAILURE, "kevent wait");
        } else if (ret > 0) {
            if (tevent.flags & EV_ERROR)
                errx(EXIT_FAILURE, "Event error: %s", strerror(event.data));
            else
                printf("Something was written in '%s'\n", argv[1]);
        }
    }

    /* kqueues are destroyed upon close() */
}
```

```
(void)close(kq);
(void)close(fd);
}
```

ERRORS

The **kqueue()** system call fails if:

- | | |
|----------|--|
| [ENOMEM] | The kernel failed to allocate enough memory for the kernel queue. |
| [ENOMEM] | The RLIMIT_KQUEUES rlimit (see <code>getrlimit(2)</code>) for the current user would be exceeded. |
| [EMFILE] | The per-process descriptor table is full. |
| [ENFILE] | The system file table is full. |

The **kevent()** system call fails if:

- | | |
|----------|--|
| [EACCES] | The process does not have permission to register a filter. |
| [EFAULT] | There was an error reading or writing the <i>kevent</i> structure. |
| [EBADF] | The specified descriptor is invalid. |
| [EINTR] | A signal was delivered before the timeout expired and before any events were placed on the kqueue for return. |
| [EINTR] | A cancellation request was delivered to the thread, but not yet handled. |
| [EINVAL] | The specified time limit or filter is invalid. |
| [EINVAL] | The specified length of the event or change lists is negative. |
| [ENOENT] | The event could not be found to be modified or deleted. |
| [ENOMEM] | No memory was available to register the event or, in the special case of a timer, the maximum number of timers has been exceeded. This maximum is configurable via the <i>kern.kq_calloutmax</i> sysctl. |
| [ESRCH] | The specified process to attach to does not exist. |

When **kevent()** call fails with EINTR error, all changes in the *changelist* have been applied.

SEE ALSO

aio_error(2), aio_read(2), aio_return(2), poll(2), read(2), select(2), sigaction(2), write(2),
pthread_setcancelstate(3), signal(3)

Jonathan Lemon, "Kqueue: A Generic and Scalable Event Notification Facility", *Proceedings of the FREENIX Track: 2001 USENIX Annual Technical Conference, USENIX Association, June 25-30, 2001*.

HISTORY

The **kqueue()** and **kevent()** system calls first appeared in FreeBSD 4.1.

AUTHORS

The **kqueue()** system and this manual page were written by Jonathan Lemon <jlemon@FreeBSD.org>.

BUGS

In versions older than FreeBSD 12.0, <sys/event.h> failed to parse without including <sys/types.h> manually.