

Linux Fast-STREAMS Porting Guide

Version 0.7a Edition 3
Updated 2005-09-14
Package streams-0.7a.3

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The OpenSS7 Project <<http://www.openss7.org/>>

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- Per Berquist
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- Others

Introduction

Concepts

1 Porting

Although each of the manual pages of supported functions and structures provides compatibility and porting information, this document attempts to gather together pertinent information concerning porting from various UNIX operating system supporting STREAMS.

The porting information is organized by the operating system from which porting is being attempted. Note that, aside from configuration details, any system not listed here that is based on SVR 4.2 MP or on another of the implementations, should start with that implementation's portability information.

Porting information is organized into sections as follows:

1.1 Base Functions

1.1.1 Message Functions

- adjmsg(9)** trim bytes from the front or back of a *STREAMS* message
- allocb(9)** allocate a *STREAMS* message and data block
- bufcall(9)** install a buffer callback
- copyb(9)** copy a *STREAMS* message block
- copymsg(9)**
copy a *STREAMS* message
- datamsg(9)**
tests a *STREAMS* message type for data
- dupb(9)** duplicate a *STREAMS* message block
- dupmsg(9)**
duplicate a *STREAMS* message
- esballoc(9)**
allocate a *STREAMS* message and data block with a caller supplied data buffer
- freeb(9)** frees a *STREAMS* message block
- freemsg(9)**
frees a *STREAMS* message
- linkb(9)** link a message block to a *STREAMS* message
- msgdsz(9)**
calculate the size of the data in a *STREAMS* message
- msgpullup(9)**
pull up bytes in a *STREAMS* message
- pcmsg(9)** test a data block message type for priority control
- pullupmsg(9)**
pull up the bytes in a *STREAMS* message
- rmvb(9)** remove a message block from a *STREAMS* message

testb(9) test if a *STREAMS* message can be allocated

unbufcall(9)
 remove a *STREAMS* buffer callback

unlinkb(9) unlink a message block from a *STREAMS* message

1.1.2 UP Queue Functions

backq(9) find the upstream or downstream queue

bcanput(9)
 test flow control on a *STREAMS* message queue

canenable(9)
 test whether a *STREAMS* message queue can be scheduled

enableok(9)
 allow a *STREAMS* message queue to be scheduled

flushband(9)
 flushes band *STREAMS* messages from a message queue

flushq(9) flushes messages from a *STREAMS* message queue

getq(9) gets a message from a *STREAMS* message queue

inq(9) inserts a message into a *STREAMS* message queue

noenable(9)
 disable a *STREAMS* message queue from being scheduled

OTHERQ(9)
 return the other queue of a *STREAMS* queue pair

putbq(9) put a message back on a *STREAMS* message queue

putctl(9) put a control message on a *STREAMS* message queue

putctl1(9) put a 1 byte control message on a *STREAMS* message queue

putq(9) put a message on a *STREAMS* message queue

qenable(9) schedules a *STREAMS* message queue service routine

qreply(9) replays to a message from a *STREAMS* message queue

qsize(9) return the number of message on a queue

RD(9) return the read queue of a *STREAMS* queue pair

rmvq(9) remove a message from a *STREAMS* message queue

SAMESTR(9)
 test for *STREAMS* pipe or fifo

WR(9) return the write queue of a *STREAMS* queue pair

1.1.3 MP Queue Functions

- bcanputnext(9)**
test flow control on a message queue
- canputnext(9)**
test flow control on a message queue
- freezestr(9)**
freeze the state of a stream queue
- put(9)**
invoke the put procedure for a *STREAMS* module or driver with a *STREAMS* message
- putnext(9)**
put a message on the downstream *STREAMS* message queue
- putnextctl1(9)**
put a 1 byte control message on the downstream *STREAMS* message queue
- putnextctl(9)**
put a control message on the downstream *STREAMS* message queue
- qprocsoff(9)**
disables *STREAMS* message queue processing for multi-processing
- qprocson(9)**
enables *STREAMS* message queue processing for multi-processing
- strqget(9)** gets information about a *STREAMS* message queue
- strqset(9)** sets attributes of a *STREAMS* message queue
- unfreezestr(9)**
thaw the state of a stream queue

1.1.4 DDI/DKI Functions

- kmem_alloc(9)**
allocate kernel memory
- kmem_free(9)**
deallocates kernel memory
- kmem_zalloc(9)**
allocate and zero kernel memory
- cmn_err(9)**
print a kernel command error
- bcopy(9)** copy byte strings
- bzero(9)** zero a byte string
- copyin(9)** copy user data in from user space to kernel space
- copyout(9)**
copy user data in from kernel space to user space

delay(9) postpone the calling process for a number of clock ticks

drv_getparm(9)
driver retrieve kernel parameter

drv_hztomsec(9)
convert kernel tick time between microseconds or milliseconds

drv_htztousec(9)
convert kernel tick time between microseconds or milliseconds

drv_msectohz(9)
convert kernel tick time between microseconds or milliseconds

drv_priv(9)
check if the current process is privileged

drv_usectohz(9)
convert kernel tick time between microseconds or milliseconds

drv_usecwait(9)
delay for a number of microseconds

min(9) determine the minimum of two integers

max(9) determine the maximum of two integers

getmajor(9)
get the internal major device number for a device

getminor(9)
get the extended minor device number for a device

makedevice(9)
create a device from a major and minor device numbers

strlog(9) pass a message to the *STREAMS* logger

timeout(9)
start a timer

untimeout(9)
stop a timer

mknod(9) make block or character special files

mount(9) mount and unmount filesystems

umount(9)
mount and unmount filesystems

unlink(9) remove a file

1.1.5 Some Common Extension Functions

linkmsg(9)
link a message block to a *STREAMS* message

putctl2(9) put a two byte control message on a *STREAMS* message queue

putnextctl2(9) put a two byte control message on the downstream *STREAMS* message queue

weldq(9) weld two (or four) queues together

unweldq(9) unweld two (or four) queues

1.1.6 Some Internal Functions

allocq(9) allocate a *STREAMS* queue pair

bcanget(9) test for message arrival on a band on a stream

canget(9) test for message arrival on a stream

freeq(9) deallocate a *STREAMS* queue pair

qattach(9) attach a module onto a *STREAMS* file

qclose(9) close a *STREAMS* module or driver

qdetach(9) detach a module from a *STREAMS* file

qopen(9) call a *STREAMS* module or driver open routine

setq(9) set sizes and procedures associated with a *STREAMS* message queue

1.1.7 Some Oddball Functions

appq(9) append one *STREAMS* message after another

esbbcall(9) install a buffer callback for an extended *STREAMS* message block

isdatabl(9) test a *STREAMS* data block for data type

isdatamsg(9) test a *STREAMS* data block for data type

kmem_zalloc_node(9)

msgsize(9) calculate the size of the message blocks in a *STREAMS* message

qcountstrm(9) add all counts on all *STREAMS* message queues in a stream

xmsgsize(9) calculate the size of message blocks in a *STREAMS* message

1.2 Porting from SVR 4.2 MP

This section captures portability information for SVR 4.2 MP based systems. If the operating system from which you are porting more closely fits one of the other portability sections, please see that section.

1.2.1 Differences from SVR 4.2 MP

Linux Fast-STREAMS has very few differences from *SVR 4.2 MP*. Not all *SVR 4.2 MP* functions are implemented in the base **Linux Fast-STREAMS** kernel modules. Some functions are included in the *SVR 4.2 MP* compatibility module, `'streams-svr4compat.o'`.

1.2.1.1 Priority Levels

Linux has a different concept of priority levels than *SVR 4.2 MP*. **Linux** has basically 4 priority levels as follows:

1. Preemptive

At this priority level, software and hardware interrupts are enabled and the kernel is executing with preemption enabled. This means that the currently executing kernel thread could preempt and sleep in favor of another thread of kernel execution.

This priority level only exists on preemptive (mostly 2.6) kernels.

2. Non-Preemptive

At this priority level, software and hardware interrupts are enabled and the kernel is executing with preemption disabled. This means that the currently executing kernel thread will only be interrupted by software or hardware interrupts.

This priority level exists in all kernels.

3. Software Interrupts Disabled

At this priority level, software interrupts are disabled and the kernel is executing with preemption disabled. This means that the currently executing kernel thread will only be interrupted by hardware interrupts.

This is the case when the executing thread is processing a software interrupt, or when the currently executing thread has disabled software interrupts.

This priority level exists in all kernels.

4. Interrupt Service Routines Disabled

At this priority level, hardware interrupts are disabled and the kernel is executing with preemption disabled. This means that the currently executing kernel thread will not be interrupted.

This is the case when the executing thread is processing a hardware interrupt, or when the currently executing thread has disabled hardware interrupts.

This priority level exists in all kernels.

1.2.1.2 Basic Locks

1.2.2 Commonalities with SVR 4.2 MP

1.2.3 Compatibility functions for SVR 4.2 MP

ATOMIC_INT_ADD(9)

add an integer value to an atomic integer

ATOMIC_INT_ALLOC(9)

allocate and initialize an atomic integer

ATOMIC_INT_DEALLOC(9)

deallocate an atomic integer

ATOMIC_INT_DECR(9)

decrement and test an atomic integer

ATOMIC_INT_INCR(9)

increment an atomic integer

ATOMIC_INT_INIT(9)

initialize an atomic integer

ATOMIC_INT_READ(9)

read an atomic integer

ATOMIC_INT_SUB(9)

subtract an integer value from an atomic integer

ATOMIC_INT_WRITE(9)

write an integer value to an atomic integer

itimeout(9)

perform a timeout at an interrupt level

lbolt(9)

time in ticks since reboot

LOCK(9) lock a basic lock**LOCK_ALLOC(9)**

allocate a basic lock

LOCK_DEALLOC(9)

deallocate a basic lock

LOCK_OWNED(9)

determine whether a basic lock is held by the caller

MPSTR_QLOCK(9)

release a queue from exclusive access

MPSTR_QRELE(9)

acquire a queue for exclusive access

MPSTR_STPLOCK(9)

acquire a stream head for exclusive access

MPSTR_STPRELE(9)

release a stream head from exclusive access

major(9) get the internal major number of a device

makedev(9) make a device number from internal major and minor device numbers

minor(9) get the internal minor number of a device

RW_ALLOC(9) allocate and initialize a read/write lock

RW_DEALLOC(9) deallocate a read/write lock

RW_RDLOCK(9) acquire a read/write lock in read mode

RW_TRYRDLOCK(9) attempt to acquire a read/write lock in read mode

RW_TRYWRLOCK(9) attempt to acquire a read/write lock in write mode

RW_UNLOCK(9) release a read/write lock

RW_WRLOCK(9) acquire a read/write lock in write mode

sleep(9) put a process to sleep

SLEEP_ALLOC(9) allocate a sleep lock

SLEEP_DEALLOC(9) deallocate a sleep lock

SLEEP_LOCK(9) acquire a sleep lock

SLEEP_LOCKAVAIL(9) determine whether a sleep lock is available

SLEEP_LOCKOWNED(9) determine whether a sleep lock is held by the caller

SLEEP_LOCK_SIG(9) acquire a sleep lock

SLEEP_TRYLOCK(9) attempt to acquire a sleep lock

SLEEP_UNLOCK(9) release a sleep lock

spl0(9) set priority level 0

spl1(9) set priority level 1

spl2(9) set priority level 2

spl3(9) set priority level 3

spl4(9) set priority level 4
spl5(9) set priority level 5
spl6(9) set priority level 6
spl7(9) set priority level 7
spl(9) set priority level
splx(9) set priority level x
SV_ALLOC(9)
 allocate a basic condition variable
SV_BROADCAST(9)
 broadcast a basic condition variable
SV_DEALLOC(9)
 deallocate a basic condition variable
SV_SIGNAL(9)
 signal a basic condition variable
SV_WAIT(9)
 wait on a basic condition variable
SV_WAIT_SIG(9)
 interruptible wait on a basic condition variable
TRYLOCK(9)
 try to lock a basic lock
UNLOCK(9)
 unlock a basic lock
vtop(9) convert virtual to physical address
wakeup(9) wake a process

1.2.4 Configuration ala SVR 4.2 MP

1.3 Porting from AIX 5L Version 5.1

1.3.1 Differences from AIX 5L Version 5.1

1.3.2 Commonalities with AIX 5L Version 5.1

1.3.3 Compatibility Functions for AIX 5L Version 5.1

putctl2(9) put a 2 byte control message on a *STREAMS*

splstr(9) set or restore priority levels

splx(9) set or restore priority levels

unweldq(9)
unweld two pairs of streams queues

weldq(9) weld together two paris of streams queues

mi_bufcall(9)
reliable alternative to **bufcall**(9)

mi_close_comm(9)
STREAMS common minor device close utility

mi_next_ptr(9)
STREAMS minor device list traversal

mi_open_comm(9)
STREAMS common minor device open utility

mi_prev_ptr(9)
STREAMS minor device list traversal

str_install(9)
install a *STREAMS* module or driver

wantio(9) perform direct I/O from a *STREAMS* driver

wantmsg(9)
provide a filter of wanted messages from a *STREAMS* module

1.3.4 Configuration ala AIX 5L Version 5.1

1.4 Porting from HP-UX 11.0i v2

1.4.1 Differences from HP-UX 11.0i v2

1.4.2 Commonalities with HP-UX 11.0i v2

1.4.3 Compatibility Functions for HP-UX 11.0i v2

putctl2(9) put a 2 byte control message on a *STREAMS* message queue

putnextctl2(9)
put a 2 byte control message on the downstream *STREAMS* message queue

unweldq(9)
unweld two pairs of streams queues

weldq(9) weld together two paris of streams queues

str_install(9)
install a *STREAMS* module or driver

str_uninstall(9)
uninstall a *STREAMS* module or driver

streams_get_sleep_lock(9)
provide access to the global sleep lock

streams_put(9)
invoke the put procedure for a *STREAMS* module or driver with a *STREAMS* message

1.4.4 Configuration ala HP-UX 11.0i v2

1.5 Porting from OSF/1 1.2/Digital UNIX

1.5.1 Differences from OSF/1 1.2/Digital UNIX

1.5.2 Commonalities with OSF/1 1.2/Digital UNIX

1.5.3 Compatibility Functions for OSF/1 1.2/Digital UNIX

unweldq(9)

unweld two pairs of streams queues

weldq(9) weld together two pairs of streams queues

lbolt(9) time in ticks since reboot

puthere(9)

invoke the put procedure for a *STREAMS* module or driver with a *STREAMS* message

streams_close_comm(9)

common minor device close utility

streams_open_comm(9)

common minor device open utility

streams_open_ocomm(9)

common minor device open utility

strmod_add(9)

add a *STREAMS* module

strmod_del(9)

delete a *STREAMS* module or driver from the kernel

time(9) (undoc)

1.5.4 Configuration ala OSF/1 1.2/Digital UNIX

1.6 Porting from UnixWare 7.1.3 (OpenUnix 8)

1.6.1 Differences from UnixWare 7.1.3 (OpenUnix 8)

1.6.2 Commonalities with UnixWare 7.1.3 (OpenUnix 8)

1.6.3 Compatibility Functions for UnixWare 7.1.3 (OpenUnix 8)

The following compatibility functions are in addition to all SVR 4.2 compatibility functions.

allocb_physreq(9)

allocate a *STREAMS* message and data block

emajor(9) get the external (real) majore device number from the device number

eminor(9) get the external extended minor device number from the device number

etoimajor(9)

convert an external major device number to an internal major device number

getemajor(9)

get the external (real) majore device number

geteminor(9)

get the external minor device number

itoemajor(9)

convert an internal major device number to an external major device number

msgphysreq(9)

cause a message block to meet physical requirements

msgpullup_physreq(9)

pull up bytes in a *STREAMS* message

msgscgth(9)

(undoc)

striocall(9)

(undoc)

1.6.4 Configuration ala UnixWare 7.1.3 (OpenUnix 8)

1.7 Porting from Solaris 9/SunOS 5.9

1.7.1 Differences from Solaris 9/SunOS 5.9

1.7.2 Commonalities with Solaris 9/SunOS 5.9

1.7.3 Compatibility Functions for Solaris 9/SunOS 5.9

_fini(9)

_info(9)

_init(9)

attach(9) attach a device to the system or resume a suspended device

ddi_create_minor_node(9)

create a minor node for this device

ddi_driver_major(9)

find the major device number associated with a driver

ddi_driver_name(9)

return normalized driver name

ddi_get_cred(9)

get a reference to the credentials of the current user

ddi_getiminor(9)

ddi_get_instance(9)

get device instance number

ddi_get_lbolt(9)

get the current value of the system tick clock

ddi_get_pid(9)

ddi_get_soft_state(9)

ddi_get_time(9)

get the current time in seconds since the epoch

ddi_remove_minor_node(9)

remove a minor node for a device

ddi_removing_power(9)

ddi_soft_state(9)

ddi_soft_state_fini(9)

ddi_soft_state_free(9)

ddi_soft_state_init(9)

ddi_soft_state_zalloc(9)

ddi_umem_alloc(9)

allocate page aligned kernel memory

ddi_umem_free(9)

detach(9) detach a device from the system or suspend a device

getinfo(9)

identify(9) determine if a driver is associated with a device

install_driver(9)

install a device driver

mod_info(9)

provides information on a loadable kernel module to the *STREAMS* executive

mod_install(9)

installs a loadable kernel module in the *STREAMS* executive

mod_remove(9)

removes a loadable module from the *STREAMS* executive

power(9) power a device attached to the system

probe(9)

qbufcall(9)

install a buffer callback

qtimeout(9)

start a timer associated with a queue

queclass(9)

qunbufcall(9)

quntimeout(9)

qwait(9) wait for a queue message

qwait_sig(9)

wait for a queue message or signal

qwriter(9)

1.7.4 Configuration ala Solaris 9/SunOS 5.9

1.8 Porting from SUPER-UX

1.8.1 Differences from SUPER-UX

1.8.2 Commonalities with SUPER-UX

1.8.3 Compatibility Functions for SUPER-UX

`lbolt(9)` time in ticks since reboot

1.8.4 Configuration ala SUPER-UX

1.9 Porting from UXP/V

1.9.1 Differences from UXP/V

1.9.2 Commonalities with UXP/V

1.9.3 Compatibility Functions for UXP/V

1.9.4 Configuration ala UXP/V

1.10 Porting from Linux STREAMS (LiS) 2.18.1

1.10.1 Differences from LiS 2.18.1

1.10.2 Commonalities with LiS 2.18.1

1.10.3 Compatibility Functions for LiS 2.18.1

lis_appq(9)

append one *STREAMS* message after another

lis_date(9)

lis_esbcall(9)

install a buffer callback for an extended *STREAMS* message block

lis_find_strdev(9)

lis_mknod(9)

make block or character special files

lis_mount(9)

mount a file system

lis_OTHER(9)

return the other queue of a *STREAMS* queue pair

lis_register_strdev(9)

register a *STREAMS* device

lis_register_strmod(9)

register a *STREAMS* module

lis_umount2(9)

unmount a file system

lis_umount(9)

unmount a file system

lis_unlink(9)

remove a file

lis_unregister_strdev(9)

unregister a *STREAMS* device

lis_unregister_strmod(9)

unregister a *STREAMS* module

lis_version(9)

lis_xmsgsize(9)

calculate the size of message blocks in a *STREAMS* message

1.10.4 Configuration ala LiS 2.18.1

2 Development

2.1 Portable *STREAMS* Drivers and Modules

In the process of creating the **Linux Fast-STREAMS** subsystem in such a way so as to facilitate portability of *STREAMS* drivers and modules from a wide range of *UNIX* operating system variants, a number of guidelines for the development of portable *STREAMS* drivers and modules have been developed. These guidelines, when adhered to, will allow the resulting driver or module to be ported to another *STREAMS* implementation with minimal effort. These portability guidelines are collected here.

2.1.1 Memory Allocation

Portable *STREAMS* modules and drivers will always allocate memory using the SVR4 memory allocators/deallocators: **kmem_alloc(9)**, **kmem_zalloc(9)** and **kmem_free(9)**.

Additional eligible allocators are:

rmallocmap(9) **rmfreemap(9)** **rmalloc(9)** **rmalloc_wait(9)** **rmfree(9)** **rminit(9)** **rmsetwant(9)** **rmwanted(9)**

Unfortunately, these resource map allocators are not available on *AIX* so, if portability to the *AIX PSE* is important, then do not use these allocators.

Additional eligible allocators are:

kmem_fast_alloc(9) **kmem_fast_free(9)**

2.1.2 Alignment of Message Buffers

2.1.3 Disabling and Enabling Queue Procedures

Portable *STREAMS* modules and drivers will always call **qprocson(9)** before returning from its queue open procedure (see **qopen(9)**).

Portable *STREAMS* modules and drivers will always call **qprocsoff(9)** upon entering its queue close procedure (see **qclose(9)**).

2.1.4 Freezing and Unfreezing Streams

2.1.5 Passing Messages from Interrupt Service Routines

2.1.6 Timeout Call Back and Link Identifiers

Although buffer callbacks identifiers (see **bufcall(9)**), timeout identifiers (see **timeout(9)**), and multiplexing driver link identifiers (see *L_LINK* and *L_PLINK* under **streamio(2)**), are often illustrated as small integer numbers, with some *STREAMS* implementations, including **Linux Fast-STREAMS**, these identifiers are kernel addresses (pointers) and are never small integer values like 1, 2, or 3.

Also, there is no guarantee that the identifier will be positive. It is guaranteed that the returned identifier will not be zero (0). Zero is used by these function as a return value to indicate an error.

Portable *STREAMS* drivers and modules will not depend upon the returned identifier from **bufcall(9)**, **timeout(9)** or **streamio(2)** as being any specific range of value. Portable drivers

and modules will save any returned identifiers in data types that will not lose the precision of the identifier.

2.1.7 Synchronization with Timeouts and Callback Functions

2.1.8 Synchronization with Callout Functions

2.1.9 Synchronization of Drivers and Modules

2.1.10 Special *STREAMS* Message Types

2.1.11 Use of Message Allocation Priorities

2.1.12 Registration/Deregistration and Device Numbering

UNIX Device Numbering

In versions of *UNIX System V* previous to *Release 4*, the major and minor device numbers were each 8 bit, and they were packed into a 16 bit word (usually a C Language *short* variable). Under *UNIX System V Release 4*, the device numbers are held in a `'dev_t'` variable, which is often implemented as a 32 bit integer. The minor device number is held as 14 bits, and a further 8 bits are used for the major device number. `'dev_t'` is often referred to as the "expanded device type", since it allows many more minor devices than before.

Many drivers were written for earlier releases, and may eventually be ported to *UNIX System V Release 4*. In earlier releases, some manufacturers got around the 256 minor device number limit by using multiple major device numbers for a device. Devices were created with different major device numbers (the external major device number) but they all mapped to the same device driver entry in the device switch tables (the internal device number). Even under this scheme, each major device could only support 256 minor devices, but the driver could support many more. This has been recognized in *UNIX System V Release 4*, and functions are provided to do this mapping; for example, the function `etoimajor()` and so on, give a machine independent interface to the device number mapping.¹

Linux Device Numbering

Versions of the **Linux** kernel in the 2.4 kernel series and prior to 2.6 also provided an 8 bit major device number and an 8 bit minor device number grouped into a 16-bit combined device number. Linux 2.6 kernels (and some patched 2.4 kernels) now have larger device numbers. These extended device numbers are 12 bits for major device number and 20 bits for minor device number, with 32 bits for the combined device number.

LiS Device Numbering

LiS prior to the 2.18.0 release was incapable of providing an internal representation of the device number and the number of minor device numbers for a device driver was restricted to

¹ *The Magic Garden Explained*

256.² Many **OpenSS7** device drivers written for *LiS* would allocate additional major device numbers if required. Good examples of devices that require more than 255 minor device numbers are INET clone devices, SCTP streams, SS7 signalling link streams, MG media channels, etc. These streams are often *LPLINK*ed under a multiplexing driver and do not even consume a system file descriptor.

Linux Fast-STREAMS Device Numbering

Linux Fast-STREAMS began with extended device numbering. The ‘**specfs**’ shadow special character device filesystem used by **Linux Fast-STREAMS** uses the ‘**inode**’ number to hold the ‘**dev_t**’ device number instead of the ‘**inode->i_rdev**’, which on older kernels is only a 16-bit *short*.

In earlier versions of **Linux Fast-STREAMS**, the internal device numbering is 16-bits for major device number and 16-bits for minor device number. This will soon be changed to 12-bits for major device number and 20-bits for minor device number to accomodate the newer **Linux** scheme.

On 2.6 **Linux** kernels that support the newer extended device numbers, external device numbers and internal device numbers will be the same. On 2.4 **Linux** kernels with the older 16-bit device numbers, external device number and internal device numbers will differ. In some situations, an internal device number can exist with no corresponding external device number (accessed only via a clone device or direct access to the mounted ‘**specfs**’ shadow special character device filesystem).

etoimajor(9)

change external to internal major device number

getemajor(9)

get external major device number

geteminor(9)

get external minor device number

itoemajor(9)

change internal to external major device number

² Actually, 255 as the kernel reserved minor device number 255 for expansion.

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