

Index

Numbers

16-bit ports, 240, 242
32-bit ports, 240
 accessing, 240
 string functions for, 242
8-bit ports, 240
 reading/writing, 240
 string functions for, 242

A

abstractions (hardware), 318
access
 blocking open requests, 176
 character (char) drivers, 6, 43–49
 to device files, 173–179
DMA (see DMA)
 to drivers, 47
interfaces, 7
I/O memory, 249, 250, 252
ISA memory, 253
kobjects, 365
locking, 121
management, 108
NUMA systems, 216, 417
PCI, 305
 configuration space, 315
 I/O and memory spaces, 316
policies, 3
ports, 255
 different sizes, 240
 from user space, 241
restriction of, 144, 174

seqlocks, 127
unaligned data, 300
access_ok function, 142
ACTION variable, 399
adding
 devices, 392–395
 drivers, 396
 locking, 109
 VMAs, 426
Address Resolution Protocol (see ARP)
addresses
 bounce buffers, 445
 bus (see bus addresses)
 buses, 443
 hardware, 508, 515
 hardware (see hardware addresses)
 MAC, 504, 532–534
 PCI, 303, 452
 remapping, 434
 resolution (network management), 5
 resolving, 532
 spaces, generic I/O, 316
 types, 413
 virtual (conversion), 444
aio_fsync operation, 438
algorithms (lock-free), 123
alignment
 of data, 293
 unaligned data access, 300
allocating
 major device numbers, 46–49
 memory, 60–62
 by page, 221

We'd like to hear your suggestions for improving our indexes. Send email to index@oreilly.com.

allocation, 249, 255
of block drivers, 468
of buffers, 530
of device numbers, 45
of DMA buffers, 442
dynamic allocation of major numbers, 46
of gendisk structures, 468
of I/O ports, 239
of memory, 60–63
 boot time, 230, 234
 flags, 215, 218, 231
 I/O, 249, 255
 kmalloc allocation engine, 213–217
 lookaside caches, 217–224, 232
 per-CPU variables, 228–230
 vmalloc allocation function, 224–228
page-oriented functions, 221, 233
of snull drivers, 503
of socket buffers, 522, 530
structures (registration), 55–57
of urbs, 354
alloc_netdev function, 504
alloc_pages interface, 223
alloc_skb function, 530
alloc_tty_driver function, 549
Alpha architecture, porting and, 243
alternatives to locking, 123–130
API (application programming interface)
 spinlocks, 117
 timers, 198
application programming interface (see API)
applications versus kernel modules, 18–22
architecture
 EISA, 323
 M68k (porting and), 243
 MCA, 322
 NuBus, 324
 PCI, 302–319
 PowerPC (porting and), 244
 S/390, 402
 SBus, 324
 SPARC, 244
 Super-H, 244
 VLB, 323
 x86 (interrupt handlers on), 268
zSeries, 402
arguments
 cache, 218
 flags, 213
 interrupt handlers, 272
 ioctl method, 141
kmalloc size, 216
sfile, 87
ARM architecture, porting and, 243
ARP (Address Resolution Protocol), 504
 Ethernet and, 532
IFF_NOARP flag and, 504, 509
overriding, 533
arrays
 bi_io_vec, 482
 block drivers, 468
 memory maps, 417
 parameters (declaration of), 37
 quantum sets (memory), 61
asm directory, 19
assignment
 dynamic allocation of major numbers, 46
 of hardware addresses, 515
 of IP numbers, 499
 of parameter values, 35–37
asynchronous DMA, 441
asynchronous I/O, 437–440
asynchronous notification, 169–171
asynchronous running of timers, 197
asynctest program, 169
atomic context (spinlocks), 118
atomic variables, 124
atomic_add operation, 125
atomic_dec operation, 125
atomic_dec_and_test operation, 125
atomic_inc operation, 125
atomic_inc_and_test operation, 125
atomic_read operation, 125
atomic_set operation, 125
atomic_sub operation, 125
atomic_sub_and_test operation, 125
atomic_t count field (memory), 417
attributes
 binary (kobjects), 374
 buses, 380
 data (firmware), 407
 default (kobjects), 372
 deleting, 374, 381
 devices, 383, 407
 drivers, 386
 loading (firmware), 407
 nondefault (kobjects), 373
authorization, 8
autodetection, 264
automatic, IRQ number detection, 264

B

back-casting kobject pointers, 365
barriers
 memory, 237, 238, 255
 requests, 485
base module parameter, 247
baud rates (tty drivers), 562
BCD (binary-coded decimal) forms, 346
bEndpointAddress field (USB), 330
bibliography, 575
big-endian byte order, 293
bi_io_vec array, 482
binary attributes (kobjects), 374
binary-coded decimal (BCD) forms, 346
bin_attribute structure, 374
bInterval field (USB), 331
bio structure, 482, 487
bitfields (ioctl commands), 137, 180
bits
 clearing, 269
 operations, 126
 specifications, 246
BLK_BOUNCE_HIGH symbol, 480
blk_cleanup_queue function, 479
blkdev_dequeue_request function, 479
blk_queue_hardsect_size function, 470
blk_queue_segment_boundary function, 481
block devices, 7
block drivers
 command pre-preparation, 491
 functions, 494–496
 operations, 471–474
 registration, 465–470
 request processing, 474–491
 TCQ, 492–493
block_fsync method, 167
blocking
 I/O, 147–162, 176
 open method, 176
 operations, 151
 release method, 176
bmAttributes field (USB), 330
BogoMips value, 195
boot time (memory allocation), 230, 234
booting (PCI), 306
bottom halves
 interrupt handlers, 275–278
 tasklets and, 276
bounce buffers, 445
 block drivers, 480
 streaming DMA mappings and, 449
bridges, 303

BSS segments, 419
buffers
 allocation of, 530
 bounce, 445
 block drivers, 480
 streaming DMA mappings and, 449
 circular, 78, 123
 DMA (unmapping), 449
 freeing, 531
 I/O, 151
 large (obtaining), 230, 234
 output, 152
 overrun errors, 9, 95
 for printk function, 78
 ring (DMA), 441
 socket (see socket buffers)
 sockets, 522, 528–532
 synchronization, 452
 transfers, 448
 tty drivers, 558
 USB, 338
 user space (direct I/O), 436
 write-buffering example, 282
bugs (see debugging; troubleshooting)
BULK endpoints (USB), 330
bulk urbs (USB), 343
bus_add_driver function, 396
BUS_ATTR macro, 380
bus_attribute type, 380
buses
 addresses, 413, 443
 attributes, 380
 functions, 409
 IEEE1394 (Firewire), 400
 iteration, 379
 Linux device model, 377–381
 match function, 379
 methods, 379
 PCI (see PCI)
 registers, 445
 registration, 378
 USB (see USB)
bus_for_each_dev function, 380
bus_register function, 378
bus_type structure, 378
busy loops, 191
busy-waiting implementation, 190
bytes
 CSIZE bitmask, 561
 order, 293
 orders, 300

C

caches

- argument, 218
- coherency issues, 445
- lookaside, 217–224, 232
- troubleshooting, 237, 425

calling

- current process, 21
- firmware, 407
- ioctl method, 136
- ioremap function, 249
- memory barriers, 238
- perror calls, 93
- preparation functions, 492
- release, 174

cancellation of urbs, 345

capabilities, restricted operations and, 144

capability.h header file, 144, 181

capable function, 145, 181

CAP_DAC_OVERRIDE capability, 144

- single-user access to devices, 175

CAP_NET_ADMIN capability, 144

CAP_SYS_ADMIN capability, 144

CAP_SYS_MODULE capability, 144

CAP_SYS_RAWIO capability, 144

CAP_SYS_TTY_CONFIG capability, 144

card select number (CSN), 321

cardctl utility, 3

carrier signals, 528

cdev structure, 56

change_bit operation, 126

change_mtu method, 513

- improving performance using socket buffers, 522

channels, DMA, 454–456

char *buffer field (request structure), 477

char bus_id field, 382

char disk_name field (gendisk), 467

char (character) drivers, 6

access, 43–49

asynchronous notification, 169–171

defining mechanism of, 42

files

access to, 173–179

operations, 49–53

structures, 53

inode structure, 55

I/O, 147–162

ioctl method, 135–147

llseek method, 171

memory usage (scull), 60–63

open method, 58–59

poll method, 163–169

read method, 63–69

readv calls, 69

registration, 55–57

release method, 59

scull (design of), 42

select method, 163–169

testing, 70

version numbers, 43

write method, 63–69

writerv calls, 69

char name field (net_device structure), 506

char *name variable (USB), 352

character drivers (see char drivers)

chars_in_buffer function, 558

check_flags method, 52

CHECKSUM_ symbols, 523

circular buffers, 123

DMA ring buffers, 441

implementing interrupt handlers, 270

for printk function, 78

claim_dma_lock function, 457

class register (PCI), 309

classes

devices, 5, 362, 390

functions, 410

interfaces, 391

Linux device model, 387–391

management, 389

modules, 5–8

class_id field, 390

class_simple interface, 388

class_simple_create function, 404

class_simple_device_add function, 404

class_simple_device_remove function, 405

cleanup function, 32

clear_bit operation, 126

clear_dma_ff function, 458

clearing bits on interface boards, 269

clock ticks (see jiffies, values)

clocks, 208

cycles (counting), 186

(see also time)

cloning devices, 177

close function (tty drivers), 553–556

close method, 59

vm_operations_struct structure, 421

cmd field (request structure), 492

coarse-grained locking, 122

code

concurrency in, 20

delaying execution of, 196

execution, 190–196, 209
hello world module, 16–18
inline assembly (example), 187
ISA, 321
kernels (see kernels)
memory (scull), 107
module requirements, 30
runtime, 5
scilluid, 175
sleeps, 158
test system setup, 15
user space programming, 19, 37–39
coherency
 caches, 445
 DMA, 446
command pre-preparation (block drivers), 491
command-oriented drivers, 146
commands
 dmesg, 77
 FIOASYNC, 141
 FIOCLEX, 141
 FIONBIO, 141
 FIONCLEX, 141
 FIOQSIZE, 141
 F_SETFL fcntl, 169
 F_SETOWN, 169
 gdb, 99
 ifconfig
 net_device structure and, 506
 opening network drivers, 515–516
 snuff interfaces, 501
 ioctl, 137, 140
 creating, 180
 customizing for networking, 535
 implementation, 145
 printk (see printk function)
 SIOCDEVPRIVATE, 535
 strace, 91
 wc, 92
 (see also functions)
communication with user space, 362
compilers
 gcc, 188
 optimizations, 236
compiling
 char drivers, 70
 modules, 23–25
complete function (urbs), 345
complete module, 115

completion
 of DMA, 458
request functions, 486
semaphores, 114–116
urbs, 345
concurrency
 alternatives to locking, 123–130
 controlling transmission, 518
 debugging, 21
 in kernel programming, 20
 locking
 adding, 109
 traps, 121–123
 management, 107–109
 scull (troubleshooting memory), 107
 semaphores
 completion, 114–116
 implementation, 110–114
 spinlocks, 116–121
 transmission, 518
CONFIG_ACPI_DEBUG option, 75
CONFIG_DEBUG_DRIVER option, 75
CONFIG_DEBUG_INFO option, 74
CONFIG_DEBUG_KERNEL option, 73
CONFIG_DEBUG_PAGEALLOC option, 74
CONFIG_DEBUG_SLAB option, 73
CONFIG_DEBUG_SPINLOCK option, 74
CONFIG_DEBUG_SPINLOCK_SLEEP option, 74
CONFIG_DEBUG_STACKOVERFLOW option, 74
CONFIG_DEBUG_STACK_USAGE option, 74
CONFIG_IKCONFIG option, 75
CONFIG_IKCONFIG_PROC option, 75
CONFIG_INIT_DEBUG option, 74
CONFIG_INPUT_EBUG option, 75
CONFIG_KALLSYMS option, 74
CONFIG_MAGIC_SYSRQ option, 74
CONFIG_PROFILING option, 75
CONFIG_SCSI_CONSTANTS option, 75
configuration
 cdev structure, 56
 char drivers, 45
 dynamic allocation of major numbers, 46
 internal representation of device numbers, 44
 major/minor numbers, 43
 (see also char drivers)

configuration (*continued*)
coherent DMA mappings, 446
critical sections, 109
DMA controllers, 456–459
drivers, 35–37
ether_setup function, 507–514
interrupt handlers, 259–269
kernels, 73–75
line settings (tty drivers), 560–566
multicasting, 539
net_device structure, 502
network devices, 512
parameter assignment, 35–37
PCI, 306
 accessing configuration space, 315
 registers, 308
serial lines, 565
single-page streaming mappings, 450
snl drivers, 498–502
streaming DMA mappings, 448
test system setup, 15
timeouts, 193
USB interfaces, 332
 version dependency, 26
CONFIG_USB_DYNAMIC_MINORS
 configuration option, 353
connections
 Firewire, 400
 IP numbers, 500
 network drivers to kernels, 502–514
 PCI (see PCI)
 /proc file hierarchies, 86
 USB (see USB)
 (see also hotplugs)
connectors (ISA), 323
console_loglevel variable, 77
 debugging system hangs, 97
consoles
 messages (redirecting), 77
 wrong font on, 147
const char *dev_name functions, 260
const char *name field (PCI registration), 311
const char *name function, 348
const struct pci_device_id *id_table field (PCI
 registration), 311
const struct usb_device_id *id_table
 function, 348
constructor function
 (kmem_cache_create), 218
CONTROL endpoints (USB), 329
control functions (queues), 480
control urbs (USB), 343

controllers (PCI), 318
controlling
 transmission concurrency, 518
 urbs (USB), 354
 by writing control sequences, 146
conventional memory, I/O registers, 236
 (see also memory)
conversion (virtual addresses), 444
copying (cross-space), 64
core files, 99
counters
 jiffies, 184
 reference (kobjects), 366
 registers, 186
 TSC, 186
counts (interrupts), 566
CPU modalities (levels), 20
create_module system call, 226
create_proc_read_entry function, 86
creating
 queues, 479
 urbs (USB), 341
critical sections, 109
cross-space copying, 64
CRTSCTS bitmask, 561
CSIZE bitmask, 561
CSN (card select number), 321
CSTOPB bitmask, 561
current process, 21, 40
current time, retrieving, 188–190
current.h header file, 21
currenttime file (jit module), 189
custom
 data types, 291
 ioctl methods for networking, 535
cycles_t type, 187

D

daemons
 klogd, 17, 77
 syslogd, 79
data
 explicitly sizing, 290
 physical packet transport, 501
 transferring with DMA, 440–459
 unaligned, portability and, 293
data attribute (firmware), 407
data functions (USB), 358
data structures, 49
 file operations, 49–53
 portability of, 294

data types
for explicitly sizing data, 290
`inptr_t` (C99 standard), 289
`int`, 289
interface-specific, 291
loose typing for I/O functions, 292
mixing different, 289
portability and, 288–292
standard C types, 288
`u8`, `u16`, `u32`, `u64`, 290
`uint8_t/unit32_t`, 290
`dataalign` program, 294
`datasize` program, 288
`dd` utility and scull driver example, 61
deadline schedulers (I/O), 478
deadlocks, avoiding, 117
(see also locking)
debugging, 73–105
 concurrency, 21
 using a debugger, 99–105
 using Dynamic Probes, 105
interrupt handlers, 273
with ioctl method, 90
using kdb kernel debugger, 101–103
kernels
 monitoring, 91
 by printing, 75–82
 by querying, 82–91
 support, 73–75
using kgdb, 103
levels (implementation of), 81
using LTT, 105
locked keyboard, 97
by printing, 81
by querying, 91
system faults, 93–98
system hangs, 96
using User-Mode Linux, 104
(see also troubleshooting)
declaration of array parameters, 37
`DECLARE_TASKLET` macro, 276
default attributes (`kobjects`), 372
`default_attrs` field (`kobjects`), 372
`DEFAULT_CONSOLE_LOGLEVEL`, 77
`DEFAULT_MESSAGE_LOGLEVEL`, 77
delaying execution of code, 190–196, 209
deleting
 attributes, 374, 381
 devices, 395
 drivers, 396
 mappings (DMA), 448
 `/proc` files, 86

queues, 479
symbolic links, 375
`del_timer_sync` function, 200
dentry field (file structure), 54
dependency
 platform, 27
 version, 26
dereferencing memory addresses, 289
descriptors (USB), 358
design
 concurrency, 107–109
 policy-free drivers, 3
 of scull, 42
 (see also configuration)
desktops
 PCI (see PCI)
 USB (see USB)
destroying urbs (USB), 341
destructor function
 (`kmem_cache_create`), 218
`/dev` directory, 43
`/dev` nodes, 6
 char devices and, 43
 dynamic major number allocation, 46
 `/dev/random` device, 260
 `/dev/urandom` device, 260
`/dev` tree, 403
`dev_alloc_skb` function, 530
development community (kernel),
 joining, 12
development kernels, 10
device attribute (firmware), 407
`DEVICE` variable, 402
deviceID register (PCI), 309
devices
 access to files, 173–179
 adding, 392–395
 allocation of numbers, 45
 attributes, 383
 block (see block drivers)
 caching problems, 425
 char drivers (see char drivers)
 character (see char drivers)
 classes of, 5–8, 362, 390
 cloning, 177
 concurrency, 107–109
 control operations, 5
 deleting, 395
 DMA and, 440–459
 drivers, 385
 dynamic, 397
 dynamic allocation of major numbers, 46

devices (*continued*)
FIFO, 43
file operations on, 49
files, 43
functions, 409
hotpluggable, 362
identifying type with ls command, 43
initialization, 503
input (hotplugging), 401
internal representation of numbers, 44
ioctl method, 135–147
ISA, 320
iteration, 379
Linux device model, 362–364, 381–387
 buses, 377–381
 classes, 387–391
 firmware, 405–407
 hotplug events, 375
 hotplugging, 397–405
 kobjects, 364–371
 lifecycles, 391–397
 low-level sysfs operations, 371–375
methods, 511
names of, 46
network, 400
network drivers, 497
numbers (printing), 82
operations, 513
reading and writing, 63
reading data from, 166
registration, 382, 502
SCSI, 402
scullpipe (example), 153–162
scullsing, 174
seeking, 171
single-open, 173
structures (embedding), 383
truncating on open, 59
USB (see USB)
version (see versions, numbering)
writing
 control sequences to, 146
 data to, 166
(see also drivers)
dev_id pointer (installing shared
 handlers), 278
dev_kfree_skb function, 524, 531
dev_mc_list structure, 538
DEVPATH variable, 399
dev_t i_rdev (inode structure field), 55

direct I/O, 435–440
 implementation, 460
 (see also I/O)
direct memory access (see DMA)
directories
 /dev, 43
 entries (file structure), 54
 of kernel headers, 19
 misc-progs source, 77, 162
 /proc file hierarchy connections, 86
 /proc/tty/driver, 547
 sysfs
 low-level operations, 371–375
 tty driver, 552
 USB, 333–335
 tty drivers, 566
 *dir_notify method, 52
 disable_dma function, 458
 disable_irq function, 279
 disabling
 interrupt handlers, 273
 packet transmissions, 518
 print statements, 79
 disclosure of data, 9
 disconnect function (USB), 349, 353
disks
 files versus open files, 53
 freeing, 468
 registration, 466
distribution, writing drivers for, 28
DMA (direct memory access), 440–459, 461
 block requests and, 489
 configuring controller, 456–459
 for ISA memory, 454–459
 mappings (scatter-gather), 450
 PCI devices and, 453
 registering usage, 455
 ring buffers, 441
dma_addr_t setup_dma field (USB), 338
dma_addr_t transfer_dma field (USB), 338
DMA_BIDIRECTIONAL symbol, 448, 461
DMAC (DMA controller), 454
DMA-capable memory zone, 215
 SLAB_CACHE_DMA flag and, 218
dma_free_coherent function, 447
DMA_FROM_DEVICE symbol, 448, 461
dma.h header file, 455
DMA_NONE symbol, 448, 461
dma_spin_lock, 457
DMA_TO_DEVICE symbol, 448, 461

dmesg command, 77
do_close function, 556
do_gettimeofday function, 188
do_ioctl method, 513, 535
do_IRQ function, 268
do-it-yourself probing, 266
double underscore (__) functions, 22
double-address cycle mappings (PCI), 452
doubly linked lists (portability), 299, 300
down function, 111
DRIVER_ATTR macro, 386
drivers
 adding, 396
 asynchronous notification and, 170
 attributes, 386
 block (see block drivers)
 char (see char drivers)
 command-oriented, 146
 configuring, 35–37
 deleting, 396
 devices, 385
 file operations, 49
 FireWire, 7
 functions, 409
 I2O, 7
 ioctl numbers for, 137
 iteration, 379
 lddbus, 379
 mechanism, 42
 policy versus, 2
 separation from policies, 2–4
 modules, 7
 monitoring with preprocessor, 79–81
 network, 497
 connecting to kernels, 502–514
 functions, 542–545
 interrupt handlers for, 523
 ioctl commands, 535
 link state (changes in), 528
 MAC addresses (resolution of), 532–534
 multicasting, 537–540
 opening, 515–516
 snuff, 498–502
 statistics, 536
 sbull
 initialization, 468
 request method, 475
SCSI, 7
scull (see scull)
scullc (example), 219
scullp (example), 223

scully (example), 227, 233
security issues, 8
short (example), 246
 accessing I/O memory, 252
 implementing interrupt handlers, 270
 installing interrupt handlers, 261
 probing, 266
shortprint, 282–286
structures (embedding), 386
tty, 546–550
 buffers, 558
 directories, 566
 functions, 573
 line settings, 560–566
 pointers, 553–560
 struct termios, 550–553
 tty_driver structure, 567
 tty_operations structure, 569
 tty_struct structure, 571
USB (see USB)
user-space, 37
 version (see versions, numbering)
driver_unregister function, 397
dynamic devices, 397
Dynamic Probes debugging tool, 105

E

EBUSY error, 176
EISA (Extended ISA), 323
elevators (I/O), 478
elv_next_request function, 476, 479, 492
embedding
 device structures, 383
 driver structures, 386
 kobjects, 365
enable_dma function, 458
enable_irq function, 279
enabling
 configuration for kernels, 73–75
 interrupt handlers, 273
 PCI drivers, 314
endless loops, preventing, 97
end-of-file
 poll method and, 165
 seeking relative to, 172
endpoints
 interfaces, 331
 USB, 328
entropy pool and SA_SAMPLE_RANDOM flag, 260
errno.h header file, 33
error handling during initialization, 32

errors
 buffer overrun, 95
 codes, 33
 handling at module initialization, 32–35
 read/write, 65
 values (pointers), 295
 (see also troubleshooting)
`/etc/networks` file, 500
`/etc/syslog.conf` file, 79
`ETH_ALEN` macro, 515
Ethernet
 address resolution, 532
 ARP and, 532
 non-Ethernet headers, 534
 non-Ethernet interfaces, 507
 snuff interfaces, 501
 `ether_setup` function, 504, 507–514
 `eth_header` method, 512
Ethtool, 541
events
 hotplug, 375
 race conditions, 107
exclusive waits, 159
execution
 asynchronous (interrupt mode), 197
 of code (delaying), 190–196, 209
 modes, 20
 shared interrupt handlers, 279
 threads, 109
experimental kernels, 10
exporting symbols, 28–29
`EXPORT_SYMBOL` macro, 32, 41
`EXPORT_SYMBOL_GPL` macro, 41
extended buses, 325
Extended ISA (EISA), 323

F

fast interrupt handlers, 268
`FASYNC` flag, 52, 169
`fasync` method, 52
`fasync_helper` function, 170, 182
`fasync_struct` structure, 170
faults, 19, 93–98
faulty module (oops messages), 94
`faulty_read` function, 96
`faulty_write` function, 96
`fcntl` system call, 141, 169
`fcntl.h` header file, 151
`fc_setup` function, 507
`fdatasync` system call, 167
FDDI networks, configuring interfaces, 507
`fddi_setup` function, 507

`f_dentry` pointer, 54
`f_flags` field (file structure), 54
 `O_NONBLOCK` flag, 141, 151
fiber channel devices, initializing, 507
FIFO (first-in-first-out) devices, 43
 poll method and, 165
File System header (`fs.h`), 71
`file_operations` structure, 49, 54
 declaring using tagged initialization, 53
 `mmap` method and, 424
files
 access to, 173–179
 `capability.h` header file, 144, 181
 devices, 43
 `/etc/networks`, 500
 flags, 54
 inode structure, 55
 interrupts, 262
 `ioctl.h` header file, 179
 `kmsg`, 78
 `ksyms`, 32
 modes, 53
 `net_int.c`, 507
 open, 53
 operations, 49–53
 `poll.h` header file, 163, 182
 `/proc`, 84
 `stat`, 263
 structure, 53
 structures, 49
 `uaccess.h` header file, 180
filesystems, 4
 char drivers, 43–49
 modules, 8
 nodes, 4, 7
 `/proc`, 86–90
 installing interrupt handlers, 262
 shared interrupts and, 280
 `sysfs`, 409
`filp` pointer, 53
 in `ioctl` method, 136
 in read/write methods, 63
`filp->f_op`, 54
filter hotplug operation, 376
fine-grained locking, 122
`FIOASYNC` command, 141
`FIOCLEX` command, 141
`FIONBIO` command, 141
`FIONCLEX` command, 141
`FIOQSIZEx` command, 141
FireWire, 400
 drivers, 7

firmware
calling, 407
functions, 411
interfaces, 405
Linux device model, 405–407
PCI boot time configuration, 307
first-in-first-out (FIFO) devices (see FIFO devices)
flags
argument, 213
FASYNC, 169
file, 54
GFP_ATOMIC, 214, 222
GFP_COLD, 215
GFP_DMA, 215
GFP_HIGH, 215
GFP_HIGHMEM, 215
GFP_HIGHUSER, 214
GFP_KERNEL, 221
GFP_NOFAIL, 215
GFP_NOFS, 214
GFP_NOIO, 215
GFP_NORETRY, 215
GFP_NOWARN, 215
GFP_REPEAT, 215
GFP_USER, 214
GTP_KERNEL, 214
IFF_ALLMULTI, 509
IFF_AUTOMEDIA, 510
IFF_BROADCAST, 509
IFF_DEBUG, 509
IFF_DYNAMIC, 510
IFF_LOOPBACK, 509
IFF_MASTER, 510
IFF_MULTICAST, 509
IFF_NOARP, 504, 509
IFF_NOTAILERS, 510
IFF_POINTTOPOINT, 509
IFF_PORTSEL, 510
IFF_PROMISC, 509
IFF_RUNNING, 510
IFF_SLAVE, 510
IFF_UP, 509
media_change, 473
memory allocation, 215, 218, 231
for net_device structure, 509
O_NONBLOCK (f_flags field), 166
PACKET_HOST, 530
PG_locked, 417
POLLERR, 164
POLLHUP, 164
POLLIN, 164

POLLOUT, 164
POLLPRI, 164
POLLRDBAND, 164
POLLRDNORM, 164
POLLWRBAND, 164
POLLWRNORM, 164
resource (PCI), 317
SA_INTERRUPT, 260, 286
SA_SAMPLE_RANDOM, 260
SA_SHIRQ, 260, 278
SLAB_CACHE_DMA, 218
SLABCTOR_CONSTRUCTOR, 218
SLAB_HWCACHE_ALIGN, 218
SLAB_NO_REAP, 218
TTY_DRIVER_NO_DEVFS, 553
TTY_DRIVER_REAL_RAW, 553
TTY_DRIVER_RESET_TERMIOS, 552
VM_IO, 421
Wall, 291
flips (tty drivers), 559
flow of data (tty drivers), 556
flush method, 51
close system call and, 60
flush operation, 51
flushing pending output, 167
f_mode field (file structure), 53
fonts (incorrect on console), 147
f_op pointer, 54
fops pointers, 49
forms (BCD), 346
f_pos field (file structure), 54
read_proc function and, 84
fragmentation, 442
free command, 70
free_dma function, 455
freeing
buffers, 531
device numbers, 45
disks, 468
DMA pools, 447
semaphores, 111
free_irq function, 279
free_netdev functions, 505
free_pages function, 222
F_SETFL command, 141
fcntl system call and, 169
F_SETFL fcntl command, 169
F_SETOWN command, 169
fcntl system call and, 169
fs.h header file, 71, 179
asynchronous notification and, 170
blocking/nonblocking operations, 151

fsync method, 51, 167
full class interfaces, 389
functions
 access_ok, 142
 alloc_netdev, 504
 alloc_skb, 530
 alloc_tty_driver, 549
 blk_cleanup_queue, 479
 blkdev_dequeue_request, 479
 blk_queue_hardsect_size, 470
 blk_queue_segment_boundary, 481
 block drivers, 494–496
 bus_add_driver, 396
 buses, 409
 bus_for_each_dev, 380
 bus_register, 378
 calling from modules/applications, 18
 capable, 145, 181
 chars_in_buffer, 558
 claim_dma_lock, 457
 classes, 410
 class_simple_create, 404
 class_simple_device_add, 404
 class_simple_device_remove, 405
 cleanup, 32
 clear_dma_ff, 458
 close (tty drivers), 553–556
 complete (urbs), 345
 const char *dev_name, 260
 const char *name, 348
 const struct usb_device_id *id_table, 348
 constructor (kmem_cache_create), 218
 create_proc_read_entry, 86
 del_timer_sync, 200
 dev_alloc_skb, 530
 devices, 409
 dev_kfree_skb, 524, 531
 disable_dma, 458
 disable_irq, 279
 disconnect (USB), 349, 353
 dma_free_coherent, 447
 do_close, 556
 do_gettimeofday, 188
 do_IRQ, 268
 double underscore (_), 22
 down, 111
 drivers, 409
 driver_unregister, 397
 elv_next_request, 476, 479, 492
 enable_dma, 458
 enable_irq, 279

ether_setup, 504, 507–514
fasync_helper, 170, 182
faulty_read, 96
faulty_write, 96
fc_setup, 507
fddi_setup, 507
firmware, 411
free_dma, 455
free_irq, 279
free_netdev, 505
free_pages, 222
get_cycles, 187
get_dma_residue, 458
get_fast_time, 189
get_free_page, 221
get_free_pages, 214, 221, 225
get_page, 427
get_unaligned, 293
get_user, 143, 180
get_user_pages, 435
get_zeroed_page, 221
handle_IRQ_event, 269
hello world module, 16
hippi_setup, 508
in_atomic, 198
inb, 240
inb_p, 242
in_interrupt, 198
initialization, 31–35
inl, 240
insb, 242
inserting schedules, 97
insl, 242
insw, 242
int pci_enable_device, 314
int printk_ratelimit(void), 81
int seq_escape, 88
int seq_path, 89
int seq_printf, 88
int seq_putc, 88
int seq_puts, 88
int (USB), 348
inw, 240
ioctl (tty drivers), 564
ioremap, 226, 249, 256
ioremap_nocache, 250
iounmap, 225, 250
irqreturn_t, 260
isa_readb, 254
kfree_skb, 531
kill_fasync, 170, 182

kmalloc, 61
 allocation engine, 213–217
 performance degradation issues, 222
kmap, 418
kmap_skb_frag, 532
kmem_cache_alloc, 218
kmem_cache_create, 217
kmem_cache_t type, 217
list_add, 297
list_add_tail, 297
list_del, 297
list_empty, 297
list_move, 297
list_splice, 297
locking, 121
match (buses), 379
mod_timer, 200, 202
module_init, 31
netif_carrier_off, 528
netif_carrier_ok, 528
netif_carrier_on, 528
netif_start_queue, 515
netif_stop_queue, 516, 518
netif_wake_queue, 518
network drivers, 542–545
open (tty drivers), 553–556
outb, 240
outb_p, 242
outl, 240
outsb, 242
outsl, 242
outsw, 242
outw, 240
page-oriented allocation, 221, 233
pci_map_sg, 451
pci_remove_bus_device, 395
pci_resource_, 317
pfn_to_page, 417
poll_wait, 163, 182
printk, 17, 76–82
 circular buffers for, 78
 logging messages from, 78
 seq_file interface (avoiding in), 88
 turning debug messages on/off, 79
probe (USB), 350
probe_irq_off, 265
probe_irq_on, 265
put_unaligned, 293
put_user, 143, 180
queues, 479
rdtscl, 187
read (tty drivers), 558

read_proc, 85
register_blkdev, 465
register_chrdev, 404
register_netdev, 503
relaease_dma_lock, 457
release (kobjects), 367
remap_pfn_range, 424
remove_proc_entry, 86
request (block drivers), 474–491
request_dma, 455
request_firmware, 406
SAK, 97
sbull_request, 469
schedule, 181
 execution of code (delaying), 193
 preventing endless loops with, 97
schedule_timeout, 194
scull
 open method, 58–59
 release method, 59
scull_cleanup, 179
scull_getwritespaces, 158
semaphores (see semaphores)
set_dma_addr, 457
set_dma_count, 457
set_dma_mode, 457
set_mb, 238
set_multicast_list, 539
set_rmb, 238
set_termios, 560
set_wmb, 238
sg_dma_address, 462
sg_dma_len, 462
show, 386
skb_headlen, 532
skb_headroom, 531
skb_is_nonlinear, 532
skb_pull, 532
skb_push, 531
skb_put, 531
skb_reserve, 531
skb_tailroom, 531
sleep_on, 162
acting on socket buffers, 530
spinlocks, 119
struct module *owner, 348
sysfs filesystem, 409
sys_syslog, 77
tasklet_schedule, 276
tiny_close, 556
tiocmget, 562
tiomset, 562

functions (continued)

tr_configure, 508
tty drivers, 573
tty_driver (pointers), 553–560
tty_get_baud_rate, 562
tty_register_driver, 549
unregister_netdev, 505
unsigned int irq, 260
unsigned long flags, 260
unsigned long pci_resource_end, 317
unsigned long pci_resource_start, 317
unsigned pci_resource_flags, 317
up, 111
urbs_completion, 345
usb_alloc_urb, 342
usb_bulk_msg, 356
usb_control_msg, 357
usb_fill_bulk_urb, 343
usb_fill_control_urb, 343
usb_fill_int_urb, 342
usb_get_descriptor, 358
usb_kill_urb, 345
usb_register_dev, 352
usb_set_intfdata, 351
usb_string, 359
usb_submit_urb, 344
usb_unlink_urb, 345
vfree, 225
virt_to_page, 417
vmalloc allocation, 224–228
void, 348
void barrier, 237
void blk_queue_bounce_limit, 480
void blk_queue_dma_alignment, 481
void blk_queue_hardsect_size, 481
void blk_queue_max_hw_segments, 480
void blk_queue_max_phys_segments,
 480
void blk_queue_max_sectors, 480
void blk_queue_max_segment_size, 480
void blk_start_queue, 480
void blk_stop_queue, 480
void mb, 237
void read_barrier_depends, 237
void rmb, 237
void smp_mb, 238
void smp_rmb, 238
void smp_wmb, 238
void tasklet_disable, 204
void tasklet_disable_nosync, 204
void tasklet_enable, 204
void tasklet_hi_schedule, 204

void tasklet_kill, 204
void tasklet_schedule, 204
void wmb, 237
void*dev_id, 260
wait_event_interruptible_timeout, 194
wake-up, 150, 181
wake_up, 159, 181
wake_up_interruptible, 181
wake_up_interruptible_sync, 181
wake_up_sync, 181
workqueues, 206
write (tty drivers), 556
xmit_lock, 514

G

gcc compiler, 188
gdb commands, 99, 103
gendisk structure, 467
general distribution, writing drivers for, 28
General Public License (GPL), 11
generic DMA layers, 444
generic I/O address spaces, 316
geographical addressing, 305
get_cycles function, 187
get_dma_residue function, 458
get_fast_time function, 189
get_free_page function, 221
get_free_pages function, 214, 221, 225
get_kernel_syms system call, 25
get_page function, 427
get_stats method, 512, 536
get_unaligned function, 293
get_user function, 143, 180
get_user_pages function, 435
get_zeroed_page function, 221
GFP_ATOMIC flag, 214
 page-oriented allocation functions, 221
 preparing for allocation failure, 222
GFP_COLD flag, 215
GFP_DMA flag, 215
gfp.h header file, 214
GFP_HIGH flag, 215
GFP_HIGHMEM flag, 215
GFP_HIGHUSER flag, 214
GFP_KERNEL flag, 214, 221
GFP_NOFAIL flag, 215
GFP_NOFS flag, 214
GFP_NOIO flag, 215
GFP_NORETRY flag, 215
GFP_NOWARN flag, 215
GFP_REPEAT flag, 215
GFP_USER flag, 214

global information (`net_device` structure), 506
global memory areas, 43
global messages (enabling/disabling), 79
GNU General Public License (GPL), 11
goto statement, 33
GPL (GNU General Public License), 11
group, device, 47

H

hacking kernels options, 73–75
handle_IRQ_event function, 269
hangs (system), 96–98
hard_header method, 512, 532
hard_start_transmit method, 516
hard_start_xmit method, 512, 517
hardware
 addresses, 508
 assignment of, 515
 modification of, 513
 DMA, 440, 444
 headers, 533
 adding before transmitting
 packets, 531
 building, 512
 encapsulating information, 534
 ioctl method, 135–147
 ISA, 320
 management, 235–254, 255
 net_device structure, 506
 PCI (abstractions), 318
 removable media (supporting), 472
header_cache method, 513
header_cache_update method, 514
headers
 Ethernet (see Ethernet)
 files, 19, 29
 hardware, 533
 non-Ethernet, 534
hello world module, 16–18
hierarchies
 kobjects, 368
 ksets, 370
 /proc file connections, 86
 (see also filesystems)
high memory, 216, 415
HIPPI drivers, preparing fields for, 508
hippi_setup function, 508
hostnames (snnull interfaces), 500
hotplugs
 devices, 362
 events, 375

Linux device model, 397–405
scripts, 403
hubs (USB), 334
hung system, 96
hyperthreaded processors, avoiding
deadlocks, 117
HZ (time frequency) symbol, 183, 292

I

I2O drivers, 7
IA-64 architecture
 porting and, 243
 /proc/interrupts file, snapshot of, 263
IEEE1394 bus (Firewire), 400
ifconfig command
 net_device structure and, 506
 opening network drivers, 515–516
 snnull interfaces, 501
IFF_symbols, 509, 538
IFF_ALLMULTI flag, 509
IFF_AUTOMEDIA flag, 510
IFF_BROADCAST flag, 509
IFF_DEBUG flag, 509
IFF_DYNAMIC flag, 510
IFF_LOOPBACK flag, 509
IFF_MASTER flag, 510
IFF_MULTICAST flag, 509
IFF_NOARP flag, 504, 509
IFF_NOTRAILERS flag, 510
IFF_POINTOPOINT flag, 509
IFF_PORTSEL flag, 510
IFF_PROMISC flag, 509
IFF_RUNNING flag, 510
IFF_SLAVE flag, 510
IFF_UP flag, 509
if.h header file, 509, 535
ifreq structure, 535
implementation
 asynchronous I/O, 437
 busy-waiting, 190
 of classes, 5
 of debugging levels, 81
 direct I/O, 460
 of files in /proc filesystems, 84
 interrupt handlers, 269–275
 ioctl commands, 145
 ISA (PCI), 319–322
 llseek method, 171
 mmap, 412–416, 460
 multicasting, 539
 of policies, 3
 removable media (supporting), 472

implementation (*continued*)
 semaphores, 110–114
 timers, 201
in_atomic function, 198
inb function, 240
inb_p function, 242
infinite loops, preventing, 97
information leakage, 9
in_interrupt function, 198
init scripts and loading/unloading
 modules, 48
init.h header file, 39
initialization
 completions (semaphores), 115
 devices, 503
 gendisk structure, 468
 interrupt handlers, 261
 kobjects, 366
 modules, 31–35
 mutexes, 110
 net_device structure, 503
 PCI, 306
 reader/writer semaphores, 113
 registers (PCI), 308
 sbull drivers, 468
 seqlocks, 128
 struct usb_driver structure, 349
 structures (registration), 55–57
INIT_LIST_HEAD macro, 296
inl function, 240
inline assembly code (example), 187
inode pointer in ioctl method, 136
inode structure, 55
input devices (hotplugging), 401
input files, enabling asynchronous
 notification from, 169
input module, 28
input pins, 235, 245
 reading values from parallel port, 248
insb function, 242
insl function, 242
insmod program, 5, 17, 25
 assigning parameter values, 36
 dynamically allocating major
 numbers, 48
 modprobe program versus, 29
 testing modules using, 17
installation
 interrupt handlers, 259–269, 278
 mainline kernels, 15
insw function, 242

int actual_length field (USB), 339
int data type, 289
int error_count field (USB), 341
int field
 net_device structure, 506
 PCI registration, 312
int flags field (gendisk), 467
int function (USB), 348
int interval field (USB), 341
int major field (gendisk), 467
int minor field (USB), 332
int minor_base variable (USB), 353
int minors field (gendisk), 467
int number_of_packets field (USB), 341
int pci_enable_device function, 314
int printk_ratelimit(void) function, 81
int seq_escape function, 88
int seq_path function, 89
int seq_printf function, 88
int seq_putc function, 88
int seq_puts function, 88
int start_frame field (USB), 341
int status field (USB), 339
int transfer_buffer_length field (USB), 338
interactive kernel debugger (kdb), 101–103
INTERFACE variable, 401
interfaces
 alloc_pages, 223
 block drivers
 command pre-preparation, 491
 functions, 494–496
 operations, 471–474
 registration, 465–470
 request processing, 474–491
 TCQ, 492–493
 classes, 391
 class_simple, 388
 cleanup function, 32
 configuration (USB), 332
 firmware, 405
 flags for net_device structure, 509
 full class, 389
 interface-specific data types, 291
 ksets, 370
 loopback, 498
 MII, 540
 networks, 7
 non-Ethernet, 507
 older
 char device registration, 57
 /proc file implementation, 85

parallel ports (see parallel ports)
PCI, 302–319
reader/writer semaphores, 114
`seq_file`, 87–90
`snnull`, 498–502
spinlocks, 117
timers, 198
USB, 331
version dependency, 26
VBL, 323
interface-specific data types, 291
internal functions (locking), 121
internal representation of device numbers, 44
Internet protocol (IP), 498
interrupt handlers
autodetecting IRQ numbers, 264
sharing interrupts, 281
interrupt mode
and asynchronous execution, 197
tasklets, 202–204
interrupt request lines (see IRQs)
interruptible sleeps, 157
interrupts
counts, 566
file, 262
handlers
implementation of, 269–275
installation of, 259–269
I/O, 281–286
management, 286
for network drivers, 523
preparing parallel ports, 259
`/proc` files for, 262
registration, 286
sharing, 278–281
tasklets, 276
top and bottom halves, 275–278
installation at, 261
mitigation of, 525
for network drivers, 523
PCI, 317
reports, 261
shared interrupts and, 280
timers, 183
tty drivers, 556
urbs, 342
intervals of time (data type portability), 292
`intptr_t` type (C99 standard), 289
`inw` function, 240

I/O, 167
asynchronous, 437–440
blocking, 147–162
direct, 435–440, 460
flushing pending, 167
generic address spaces, 316
hardware management, 235–254
interrupt handlers, 281–286
mapping, 249, 255
memory (access), 249
pausing, 242
PCI, 305, 316
regions, 429
registers, 236
scatter/gather, 520
.schedulers, 478
string operations, 241
transferring data with DMA, 440–459
I/O Memory Management Unit (see IOMMU)
I/O ports, parallel (see parallel ports)
I/O registers versus RAM, 236
`_IOC_DIRBITS` macro, 180
`_IOC_NRBITS` macro, 180
`_IOC_SIZEBITS` macro, 180
`_IOC_TYPEBITS` macro, 180
ioctl commands (creating), 180
ioctl function (tty drivers), 564
ioctl method, 51, 135–147
 using bitfields to define commands, 137
 block drivers, 473
 controlling devices without, 146
 customizing for networking, 535
 debugging with, 90
 network devices and, 513
 TIOCLINUX command, 77
ioctl.h header file, 137, 179
 setting up command numbers, 138
ioctl-number.txt file, 137
IOMMU (I/O memory management unit), 413, 445
ioremap function, 226, 249, 256
ioremap, 225
ioremap_nocache function, 250
iounmap function, 225, 250
IP (Internet protocol), 498
IP numbers, resolving to physical addresses, 532
`ip_summed` field (`sk_buff`), 522, 530
irq argument (interrupt number), 260

irq.h header file, 267
irqreturn_t function, 260
IRQs (interrupt request lines)
 autodetecting, 264
 statistics on, 263
ISA
 bus master DMA, 454
 devices, DMA for, 454–459
 I/O (pausing devices), 242
 memory (access), 253
 below IMB, 252–254
 DMA for, 454–459
 PCI, 319–322
isa_readb function, 254
ISOCHRONOUS endpoints (USB), 330
isochronous urbs (USB), 344
iteration of buses, 379

J

jiffies
 in busy-waiting implementation, 191
 counters, 184
 no solution for short delays, 195
 values, 184, 514
jit (just in time) module
 current time (retrieving), 189
 delaying code execution, 191
jitbusy program, 191
joysticks (hotplugging), 401
just in time (jit) module (see jit module)

K

kcore file, 99
kdataalign program, 294
kdatasize module, 289
kdb kernel debugger, 101–103
KERN_ALERT macro, 76
KERN_CRIT macro, 76
KERN_DEBUG macro, 76
kernel-assisted probing, 265
kernels
 applications (comparisons to), 18–22
 capabilities and restricted operations, 144
 code requirements, 30
 concurrency, 20
 adding locking, 109
 alternatives to locking, 123–130
 locking traps, 121–123
 management of, 107–109
 semaphore completion, 114–116
 semaphore implementation, 110–114

current process and, 21
data structures, 49
data types in
 assigning explicit sizes to, 290
 interface-specific, 291
 linked lists, 295–299
 portability, 292–295
 standard C types, 288
debuggers, 99–105
development community, joining, 12
developmental (experimental), 10
exclusive waits, 160
filesystem modules, 8
handling system faults (see system faults)
headers, 19
inode structure, 55
interrupts
 implementing handlers, 269–275
 installing handlers, 259–269
introduction to, 1
kgdb patch and, 103
linked lists, 295–299
Linux device model, 362–364
 buses, 377–381
 classes, 387–391
 devices, 381–387
 firmware, 405–407
 hotplugging, 375, 397–405
 kobjects, 364–371
 lifecycles, 391–397
 low-level sysfs operations, 371–375
loading modules into (see loading,
modules)
logical addresses, 413
mainline (installation of), 15
messages, 18
modules
 loading, 25–28
 unloading, 25
monitoring, 91
multicasting support, 538
network driver connections, 502–514
platform dependency, 27
printing, 75–82
querying, 82–91
security, 8
sources, 575
space, 19
splitting role of, 4–5
support, 73–75
symbols, 28–29
system hangs, 96

tasklets, 202–204, 211
test system setup, 15
time, 208
 measurement of lapses, 183–188
 retrieving current time, 188–190
timers, 196–202, 210
USB
 sysfs directory trees, 333–335
 transfers without urbs, 356–359
 urbs, 335–346
 writing, 346–355
versions
 dependency, 26
 numbering, 10–11
viewing, 5
virtual addresses, 414, 434
VMAs, 419–422
workqueues, 205–208, 211
 (see also modules)
kernel_ulong_t driver_info field (USB), 347
KERNEL_VERSION macro, 27
KERN_EMERG macro, 76
KERN_ERR macro, 76
KERN_INFO macro, 76
KERN_NOTICE macro, 76
KERN_WARNING macro, 76
keyboards
 debugging when locked, 97
 hotplugging, 401
keys (magic SysRq), 97
kfree, 61
kfree_skb function, 531
kgdb patch, 103
kill_fasync function, 170, 182
killing urbs, 345
klogd daemon, 17, 77
 logging messages, 78, 79
kmalloc
 flags argument, 213
 returning virtual addresses, 225
 versus vmalloc, 225
kmalloc function, 61
 allocation engine, 213–217
 performance degradation issues, 222
kmap function, 418
kmap_skb_frag function, 532
kmem_cache_alloc function, 218
kmem_cache_create function, 217
kmem_cache_t type function, 217
kmsg file, 78

kobjects, 364–371
hotplug event generation, 375
low-level sysfs operations, 371–375
nondefault attributes, 373
release functions, 367
store method, 373
symbolic links, 375
kset_hotplug_ops structure, 376
ksets, 368
 operations on, 370
 subsystems, 370
ksyms file, 32

L

lapses of time, measurement of, 183–188
laptop docking stations, 402
large buffers, obtaining, 230, 234
large file implementations (/proc files), 87
layers
 generic DMA, 444
 modularization, 28
lddbus driver, 379
ldd_driver structure, 386
LEDs, soldering to output pins, 247
levels
 CPU (modalities), 20
 debugging, 81
 message priority (see loglevels)
libraries, 19
license terms, 11
lifecycles
 Linux device model, 391–397
 objects, 363
 urbs, 335
limitations of debug messages (prink function), 81
line settings (tty drivers), 560–566
line status register (LSR), 564
link state (changes in), 528
linked lists, 295–299
 traversal of, 298
linking libraries, 18
links (symbolic), 375
Linux
 license terms, 11
 version numbering, 10
Linux device model, 362–364
 buses, 377–381
 classes, 387–391
 devices, 381–387

Linux device model (*continued*)
firmware, 405–407
hotplugging, 397–405
kobjects, 364–371
 hotplug events, 375
 low-level sysfs operations, 371–375
 lifecycles, 391–397
Linux Documentation Project web site, 576
Linux Trace Toolkit (LTT), 105
linux-kernel mailing list, 12, 299
LINUX_VERSION_CODE macro, 27, 40
list_add function, 297
list_add_tail function, 297
list_del function, 297
list_empty function, 297
list_entry macro, 297
list_for_each macro, 299
list.h header file, 299
list_head data structure, 299
list_move function, 297
lists, linked, 295–299
lists (PCI), 326
list_splice function, 297
little-endian byte order, 293
llseek method, 50, 171
loadable modules, 5
loading
 attribute (firmware), 407
 drivers, 46
 modules, 25–28
 dynamically assigned device
 numbers, 47
 parameters, 35–37
 races, 35
 local0 (IP number), 499
LocalTalk devices, setting up fields for, 507
lock method, 52
locked keyboard (debugging), 97
lock-free algorithms, 123
locking, 108
 adding, 109
 alternatives to, 123–130
 atomic variables, 124
 rules for, 122
 seqlocks, 127
 traps, 121–123
lockmeter tool, 123
loff_t f_pos (struct file field), 54
loff_t (long offset), 50, 54
LOG_BUF_LEN circular buffer, 78
logging messages (printk function), 78
logical addresses, 413

logical units (USB), 332
login process, 173
loglevels, 76
 message priorities, 17
long data type, 289
long delays (of code execution), 190
lookaside caches, 217–224, 232
loopback interfaces, 498
loops
 busy, 191
 endless, 97
 software, 195
loops_per_jiffy value, 196
low memory, 415
low-level sysfs operations, 371–375
ls command, identifying device type, 43
LSR (line status register), 564
ltalk_setup, 507
ltalk_setup function, 507
LTT (Linux Trace Toolkit), 105

M

M68k architecture (porting and), 243
MAC (medium access control)
 addresses, 504, 508
 resolution of, 532–534
 set_mac_address method and, 513
macros
 BUS_ATTR, 380
 completion, 115
 DECLARE_TASKLET, 276
 DIVER_ATTR, 386
 hello world module, 16
 INIT_LIST_HEAD, 296
 internal representation of device
 numbers, 44
 ioctl commands (creating), 180
 KERN_ALERT, 76
 KERN_CRIT, 76
 KERN_DEBUG, 76
 KERN_EMERG, 76
 KERN_ERR, 76
 KERN_INFO, 76
 KERN_NOTICE, 76
 KERN_WARNING, 76
 list_entry, 297
 list_for_each, 299
 MINOR, 71
 MODULE_DEVICE_TABLE, 311
 page_address, 417
 PAGE_SHIFT, 415
 PCI_DEVICE, 310

PCI_DEVICE_CLASS, 310
RELEVANT_IFLAG, 560
sg_dma_address, 451
sg_dma_len, 451
symbols, 29
UBS_DEVICE_VER, 347
USB_DEVICE, 347
USB_DEVICE_INFO, 347
USB_INTERFACE_INFO, 347
version dependency, 26
wait queues, 156
wait-event, 149
magic SysRq key, 97
mailing list, linux-kernel, 12
mainline kernels, installation of, 15
major device numbers, 44
 dynamic allocation of, 46–49
MAJOR macro, 71
major numbers
 char drivers, 43–49
 dynamic allocation of, 46
make command, 24
makefiles, 24
 printf function, 80
management, 4
classes, 389
concurrency, 107–109
 alternatives to locking, 123–130
 locking traps, 121–123
fragmentation, 442
hardware (I/O ports and I/O
 memory), 235–254
interrupt handlers, 286
memory, 4, 412–416
 direct I/O, 435–440
 DMA, 440–459, 461
 mapping, 416–418
 mmap device operations, 422–434
 page tables, 418
 process memory maps, 422
 scull, 60–63, 107
 VMAs, 419–422
networks, 5
physical memory, 216
power, 362
process, 4
security, 8
tasklets, 202–204
manual sleeps, 156
mapper program, 430

mapping
 deleting, 448
 DMA, 445
 I/O, 249, 255
 memory, 416–418
 mmap device operations, 422–434
 process memory maps, 422
 PCI double-address cycle, 452
 registers, 445, 450
 scatter-gather DMA, 450
 scatterlists and, 450
 single-page streaming, 450
 software-mapped memory, 250
 streaming DMA configuration, 448
 video memory, 423
match function (buses), 379
MCA (Micro Channel Architecture), 322
mdelay, 196
measurement of time lapses, 183–188
Media Independent Interface (MII), 540
media_changed method, 472
medium access control addresses (see MAC
 addresses)
memory
 allocation, 60–62
 boot time, 230, 234
 flags, 215, 218, 231
 I/O, 249, 255
 kmalloc allocation engine, 213–217
 lookaside caches, 217–224, 232
 by page, 221
 per-CPU variables, 228–230
 performance degradation issues, 222
 vmalloc allocation function, 224–228
barriers, 237, 238, 255
block drivers, 468
DMA (see DMA)
global areas, 43
hardware, 506
high, 415
I/O, 235–254, 255
ISA
 access, 253
 memory range, 252–254
limitations on, 415
locking, 109
low, 415
management, 4, 412–416
 direct I/O, 435–440
 DMA, 440–459, 461

memory, management (*continued*)
 fragmentation, 442
 mapping, 416–418
 mmap device operations, 422–434
 page tables, 418
 process memory maps, 422
 VMAs, 419–422
modules (loading), 25
page size and portability, 292
PCI, 305, 316
persistence, 43
pools, 220, 232
remapping RAM, 430
scull
 design of, 43
 troubleshooting, 107
 usage, 60–63
software-mapped (and ioremap function), 250
user space, 437
verifying user-space addresses, 142
versus I/O registers, 236
zones, 215
memory management
 DMA, 440–459
 theory of, 422
 VMAs, 422
messages
 consoles, 77
debug
 disabling, 79
 limitation of (`printk` function), 81
globally enabling/disabling, 79
kernels, 18
logging, 78
oops, 94–96
priorities (loglevels) of, 17, 76
methods, 88
 block_fsync, 167
 buses, 379
 change_mtu, 513
 check_flags, 52
 close, 59, 421
 devices, 511
 *dir_notify, 52
 do_ioctl, 513, 535
 fasync, 52
 flush, 51, 60
 fsync, 51, 167
 get_stats, 512, 536
 hard_header, 512, 532
 hard_start_transmit, 516

hard_start_xmit, 512, 517
header_cache, 513
header_cache_update, 514
ioctl, 51, 135–147
 block drivers, 473
 customizing for networking, 535
 debugging with, 90
 inode pointer in, 136
llseek, 50, 171
lock, 52
media_changed, 472
mmap, 51
next, 87
nopage, 422, 427, 431
open, 51, 58–59
 block drivers, 471
 blocking, 176
 for network devices, 511
 private_data and, 54
 requesting DMA channels, 455
 restricting simultaneous users
 and, 175
 for single-open devices, 174
 vm_operations_struct structure, 421
operations
 aio_fsync, 438
 atomic_add, 125
 atomic_dec, 125
 atomic_dec_and_test, 125
 atomic_inc, 125
 atomic_inc_and_test, 125
 atomic_read, 125
 atomic_set, 125
 atomic_sub, 125
 atomic_sub_and_test, 125
bit, 126
block drivers, 466
blocking/nonblocking, 151
change_bit, 126
clear_bit, 126
devices, 513
files, 49–53
filter hotplug, 376
flush, 51
hotplugs, 376
mmap devices, 422–434
set_bit, 126
spinlocks, 120
string, 241, 255
sysrq, 98
test_and_change_bit, 127
test_and_clear_bit, 127

test_and_set_bit, 127
test_bit, 127
vector, 69
poll, 51, 163–169, 513
poll_controller, 542
populate, 422
pread, 65
proc_read, 84
pwrite, 65
read, 50, 63–69
 arguments to, 65
 code for, 67
 configuring DMA controllers, 456
 f_pso field (file structure) and, 54
 oops messages, 95
 poll method and, 166
 rules for interpreting return values, 66
 strace command and, 92
readdir, 50
readv, 52
rebuild_header, 512
release, 51, 59
 block drivers, 471
 blocking, 176
 cloning devices, 179
 kobjects, 367
 revalidate, 473
sbull ioctl, 473
select, 163–169
select, poll method and, 51
set_config, 512
set_mac_address, 513
set_multicast_list, 510, 513, 538
show
 kobjects, 373
 seq_file interface, 88
start, 87
stop, 512
store (kobjects), 373
strace command and, 92
struct module *owner, 50
tx_timeout, 512
unsigned long, 52
write, 50, 63–69
 code for, 68
 f_pos field (file structure) and, 54
 interpreting rules for return values, 68
 oops messages, 94
 poll method and, 166
writerv, 52, 69

mice
 asynchronous notification, 170
 hotplugging, 401
Micro Channel Architecture (MCA), 322
microsecond resolution, 189
MII (Media Independent Interface), 540
minor device numbers, 44
MINOR macro, 71
minor numbers, char drivers, 43–49
MIPS processor
 inline assembly code and, 187
 porting and, 243
misc-progs directory, 77, 162
mitigation of interrupts, 525
MKDEV macro, 71
mlock system call, 39
mmap
 device operations, 422–434
 implementation, 412–416, 460
 (see also memory management)
mmap method, 51
 usage count and, 426
 vm_area_struct structure and, 420
modalities (levels), CPU, 20
models (Linux device), 362–364
 buses, 377–381
 classes, 387–391
 devices, 381–387
 firmware, 405–407
 hotplugging, 375, 397–405
 kobjects, 364–371
 lifecycles, 391–397
 low-level sysfs operations, 371–375
modes
 device modes, 47
 file modes, 53
 interrupt
 asynchronous execution, 197
 tasklets, 202–204
mode_t f_mode (struct file field), 53
mode_t mode variable (USB), 353
modprobe utility, 25, 29
 assigning parameter values, 36
 insmod program versus, 29
mod_timer function, 200, 202
modularization, layered, 28
MODULE_ALIAS macro, 41
MODULE_AUTHOR macro, 41
MODULE_DESCRIPTION macro, 41
MODULE_DEVICE_TABLE macro, 41, 311

N

name field (buses), 378
NAME variable, 401
naming
 IP numbers, 499
 sysfs directory tree (USB), 334
native DMA, 454–459
natural alignment of data items, 294
nbtest program, 162
net_device structure, 502, 506–507
 device methods of, 514
 interface flags for, 509
net_device_stats structure, 505, 536
netif_carrier_off function, 528
netif_carrier_ok function, 528
netif_carrier_on function, 528
netif_start_queue function, 515
netif_stop_queue function, 516, 518
netif_wake_queue function, 518
net_init.c file, 507
netpoll, 541
network devices, 400
network drivers, 497
 functions, 542–545
 interrupt handlers for, 523
 ioctl commands, 535
 kernel connections, 502–514
 link state (changes in), 528
 MAC addresses (resolution of), 532–534
 methods of, 514
 multicasting, 537–540
 opening, 515–516
 snull, 498–502
 statistics, 536
networks, 5
 interfaces, 7
 management, 5
next method, 87
nonblocking operations, 151
nondefault attributes (kobjects), 373
non-Ethernet headers, 534
non-Ethernet interfaces, 507
nonpreemption and concurrency, 21
nonretryable requests, 486
nonuniform memory access (NUMA) systems
 (see NUMA systems)
nopage method, 422, 427
 mremap system call with, 427
 preventing extension of mapping, 430
 remapping RAM, 431
normal memory zone, 215
notification (asynchronous), 169–171

nr_frags field, 520
NR_IRQS symbol, 267
NuBus, 324
NUMA (nonuniform memory access)
systems, 216, 417
numbering versions (see *versions, numbering*)
numbers
devices (printing), 82
interrupt, 260
IP (assignment of), 499
major and minor, 43–49
PFN, 415
root hubs (USB), 334
versions, 10–11

O

objects
kobjects, 364–371
hotplug event generation, 375
low-level sysfs operations, 371–375
(see also *kobjects*)
lifecycles, 363
sharing, 108
octets, 498
older interfaces
char device registration, 57
/proc file implementation, 85
O_NDELAY flag (*f_flags* field), 151
O_NONBLOCK flag (*f_flags* field), 54, 141, 151
read/write methods and, 166
oops messages, 94–96
open files, 53
open function (tty drivers), 553–556
open method, 51, 58–59
block drivers, 471
blocking, 176
for network devices, 511
private_data and, 54
requesting DMA channels, 455
restricting simultaneous users and, 175
for single-open devices, 174
vm_operations_struct structure, 421
opening network drivers, 515–516
operations
aio_fsync, 438
atomic_add, 125
atomic_dec, 125
atomic_dec_and_test, 125
atomic_inc, 125
atomic_inc_and_test, 125

atomic_read, 125
atomic_set, 125
atomic_sub, 125
atomic_sub_and_test, 125
bit, 126
block drivers, 466, 471–474
blocking, 151
change_bit, 126
clear_bit, 126
devices, 513
files, 49–53
filter operation, 376
flush, 51
hotplugs, 376
on ksets, 370
low-level sysfs, 371–375
methods
buses, 379
close, 421
nopage, 422
open, 421
populate, 422
(see also *methods*)
mmap devices, 422–434
nonblocking, 151
set_bit, 126
snl interfaces, 500
spinlocks, 120
string, 241, 255
sysrq, 98
test_and_change_bit, 127
test_and_clear_bit, 127
test_and_set_bit, 127
test_bit, 127
tty_operations structure, 569
vector, 69
VMAs (adding), 426
optimizations, compiler, 236
options (configuration), 73–75
ordering locking (rules for), 122
O_RDONLY flag (*f_flags* field), 54
O_SYNC flag (*f_flags* field), 54
outb function, 240
outb_p function, 242
outl function, 240
output
buffers, 152
flushing pending, 167
pins, 235, 245, 247
outsb function, 242
outsl function, 242
outsw function, 242

outw function, 240
overriding ARP, 533
overruns (buffers), 95

P

packages, upgrading, 10
PACKET_BROADCAST flag, 530
PACKET_HOST flag, 530
PACKET_MULTICAST flag, 530
PACKET_OTHERHOST flag, 530
packets
 management, 5
 multicasting, 538
 reception, 523
 reception of, 501, 521
 transmission, 501, 516–520
page frame number (PFN), 415
page_address macro, 417
page.h header file, 292
page-oriented allocation functions, 221, 233
pages
 allocators, 224
 faults caused by invalid pointers, 94
 physical addresses, 415
 size and portability, 292
 tables, 418
 I/O memory and, 249
 nopage VMA method, 427
PAGE_SHIFT macro, 415
PAGE_SHIFT symbol, 292
PAGE_SIZE symbol, 292, 423
Parallel Line Internet Protocol (see PLIP)
parallel ports, 245–248
 interrupt handlers
 disabling, 274
 preparing for, 259
 stacking driver modules, 28
parameters
 assigning values, 36
 base module, 247
 modules, 35–37
param.h header file, 183
PARENB bitmask, 561
PARODD bitmask, 561
partial data transfers
 read method, 66
 write method, 68
passwords, 9
pausing I/O, 242
PC parallel interface, 245

PCI (Peripheral Component Interconnect), 226
devices
 adding, 392–395
 deleting, 395
DMA, 453
double-address cycle mappings, 452
drivers
 adding, 396
 deleting, 396
EISA, 323
extended buses, 325
interfaces, 302–319
ISA, 319–322
lists, 326
MCA, 322
NuBus, 324
PC/104 and PC/104+, 322
SBus, 323
searching, 326
VLB, 323
pci_bus_type variable, 392
PCI_CLASS variable, 400
PCI_DEVICE macro, 310
PCI_DEVICE_CLASS macro, 310
PCI_DMA_FROMDEVICE symbol, 449
PCI_DMA_TODEVICE symbol, 449
PCI_ID variable, 400
pci_map_sg function, 451
pci_remove_bus_device function, 395
pci_resource_functions, 317
PCI_SLOT_NAME variable, 400
PCI_SUBSYS_ID variable, 400
PDEBUG/PDEBUGG symbols, 80
pending output, flushing, 167
per-CPU variables, 228–230
performance
 allocating socket buffers, 522
 degrading by allocating too much
 memory, 222
 memory barriers and, 238
 mmap method, 423
 output buffers and, 152
 string operations and, 241
Peripheral Component Interconnect (see PCI)
peripherals (DMA), 440–459
perror calls, 93
persistence of memory, 43
PFN (page frame number), 415
pfn_to_page function, 417
PG_locked flag, 417

PG_reserved flag, 417
PHYS variable, 401
physical addresses, 413
 pages, 415
 (see also addresses)
physical memory, management of, 216
 (see also memory)
pins
 9/10 of parallel connector, 259
 interrupts (generating), 271
 output, 235, 245, 247
pipes (scull), 43
platform dependency, 11, 27
 for modules, 27
 porting and, 242
/proc/stat file, 263
PLIP (Parallel Line Internet Protocol)
 using Ethernet headers, 533
 interrupt handling differences, 523
plug and play (PnP), 321
PnP (plug and play), 321
pointers
 data type portability, 295
 inode in ioctl method, 136
 kobject, 365
 scull, 61
 tty_driver function, 553–560
Point-to-Point Protocol (PPP) and interrupt
 handling differences, 523
policies
 controlling devices by printing and, 147
 memory, 4
 allocation (scull), 60, 63
 security, 8
 separation from mechanism, 2–4
policy, driver, 2–4
poll method, 51, 163–169, 513
poll_controller method, 542
POLLERR flag, 164
poll.h header file, 163, 182
POLLHUP flag, 164
POLLIN flag, 164
POLLOUT flag, 164
POLLPRI flag, 164
POLLRDBAND flag, 164
POLLRDNORM flag, 164
poll_table structure, 163, 167
poll_table_entry structure, 167
poll_wait function, 163, 182
POLLWRBAND flag, 164
POLLWRNORM flag, 164
pools
 DMA, 447
 memory, 220, 232
populate method, 422
portability, 292–299
 data types and, 288–292
 porting and, 242
ports
 access, 255
 accessing different sizes, 240
 I/O, 235–254, 255
 parallel, 245–248
 disabling interrupt handlers, 274
 preparing for interrupt handlers, 259
 platform dependency and, 242
 (see also connections; parallel ports)
POS (Programmable Option Select), 322
power management, 362
PowerPC architecture (porting and), 244
PPP (Point-to-Point Protocol) and interrupt
 handling differences, 523
pread method, 65
precision, temporal, 189
predefined commands, ioctl method, 140
 (see also commands)
preemption and concurrency, 21
preprocessor, using to monitor driver, 79–81
printing
 controlling devices by, 147
 to debug code, 81
 device numbers, 82
 from gdb debugger, 99
 interface-specific data, 291
 kernels, 75–82
 _t data items, 291
printf function, 17, 76–82
 circular buffers for, 78
 debugging with, 78
 logging messages from, 78
 seq_file interface (avoiding in), 88
 turning debug messages on/off, 79
priorities, 76
 allocation, 214
 memory, 213
 message (see loglevels)
private_data field (file structure), 54
privileged operations, 144
probe function (USB), 350
probe_irq_off function, 265
probe_irq_on function, 265
Probes, Dynamic, 105

probing, 264
do-it-yourself, 266
for IRQ numbers, 264
kernel-assisted, 265
PCI, 313
`/proc` filesystem, 86–90
installing interrupt handlers, 262
removing `/proc` entries, 86
shared interrupts and, 280
`/proc/devices` file, 46
processes
current, 21
kernel timers for, 202
kernels (splitting), 4–5
login, 173
managing, 4
memory maps, 422
opening devices for each process, 173
sleeps, 147–162
processor-specific registers, 186
`/proc/interrupts` file, 262, 280
`/proc/kcore` file, 99
`/proc/kmsg` file, 78
`/proc/*/maps`, 420
`/proc/modules` file, 40
`proc_read` method, 84
`/proc/slabinfo` file, 219
`/proc/stat` file, 263
`/proc/sys/kernel/printk` file, reading console
loglevel with, 77
`/proc/tty/driver/` directory, 547
PRODUCT variable, 401
Programmable Option Select (POS), 322
programming
concurrency in, 20
hello world module, 16–18
ISA, 321
module requirements, 30
test system setup, 15
user space, 19, 37–39
programming drivers (see writing, drivers)
programs, 3
 `asynctest`, 169
 `dataalign`, 294
 `datasize`, 288
 `insmod`, 5
 `jitbusy`, 191
 `mapper`, 430
 `nbtest`, 162
 obtaining, 12
 `rmmod`, 5
 `/sbin/hotplug` utility, 398

`setconsole`, 77
`setterm`, 147
`tcpdump`, 501
tracing, 105
`tunelp`, 3
(see also applications versus kernel
modules)
public kernel symbols, 28–29
`put_unaligned` function, 293
`put_user` function, 143, 180
`pwrite` method, 65

Q

quantums/quantum sets (memory), 61
querying kernels, 82–91
querying to debug, 91
queues
 control functions, 480
 creating/deleting, 479
 functions, 479
 network drivers, 515
 request function, 475
 request method, 478
 TCQ, 492–493
 transmissions, 518
 wait, 149, 156, 181
 workqueues, 205–208, 211, 277

R

race conditions, 21
kernel timers and, 198
module loading, 35
sequences, 107
RAM (random access memory)
 remapping, 430
 versus I/O registers, 236
random access memory (see RAM)
random numbers, 260
rates, limitations of, 81
RCU (read-copy-update), 129
`rdscl` function, 187
read function (tty drivers), 558
read method, 50, 63–69
 arguments to, 65
 code for, 67
 configuring DMA controllers, 456
 `f_pos` field (file structure) and, 54
 oops messages, 95
 poll method and, 166
 return values, rules for interpreting, 66
 strace command and, 92

read-copy-update (RCU), 129
readir method, 50
reader/writer semaphores, 113
reader/writer spinlocks, 120
reading
 blocking/nonblocking operations, 151
 from a device, 63–67
read-only /proc files, creating, 84
read_proc function, 85
readv calls, 69
readv method, 52
read/write instructions, reordering, 236
read/write position, changing, 50
rebuild_header method, 512
reception of packets, 501, 521–523
recovery, error, 33
redirecting console messages, 77
reentrant
 calls, 97
 code, 21
reference counters (kobjects), 366
regions
 generic I/O address spaces, 316
 I/O memory management, 429
register_blkdev function, 465
register_chrdev function, 404
register_netdev function, 503
registers
 counters, 186
 I/O, 236
 LSR, 564
 mapping, 445, 450
 MSR, 565
 PCI, 308, 325
 class, 309
 deviceID, 309
 subsystem deviceID, 309
 subsystem vendorID, 309
 vendorID, 309
 processor-specific, 186
scatterlists (and mapping), 450
registration
 block drivers, 465–470
 buses, 378
 char drivers, 55–57
 cleanup function, 32
 devices, 382, 502
 disks, 466
 DMA usage, 455
 interrupt handlers, 286
 module-loading races, 35

PCI drivers, 311
struct usb_driver structure, 349
tiny_tty_driver variable, 551
tracking, 33
tty drivers, 549
 USB drivers, 348
release calls, 174
release functions (kobjects), 367
release method, 51, 59
 block drivers, 471
 blocking, 176
 cloning devices, 179
 kobjects, 367
release_dma_lock function, 457
releasing spinlocks, 120
RELEVANT_IFLAG macro, 560
remap_pfn_range function, 424
remapping
 kernel virtual addresses, 434
 RAM, 430
 (see also mapping)
remote0 (IP number), 499
removable media (supporting), 472
remove_proc_entry function, 86
reordering read/write instructions, 236
repatch program, 575
reports (interrupts), 261
request_dma function, 455
request_firmware function, 406
requests
 blocking, 176
 processing, 474–491
 state of (processing), 483
requeuing/rescheduling tasks, 198
requirements, code, 30
resolution of time, 189
resolving Ethernet addresses, 532
resource flags (PCI), 317
restriction of access, 174
retrieval of current time, 188–190
return values
 interrupt handlers, 272
 switch statements, 140
revalidate method, 473
ring buffers (DMA), 441
RISC processor and inline assembly
 code, 187
rmmod program, 5, 17
 dynamically allocating major
 numbers, 48
 testing modules using, 17

roles
of device drivers, 2–4
kernels, 4–5
root hubs (USB), 334
routing, network management, 5
`rq_data_dir` field (request structure), 477
rules
locking, 121
ordering, 122
running (see execution)
runtime, code, 5
rwsems (reader/writer semaphores), 113

S

S/390 architecture, 402
porting and, 244
`SA_INTERRUPT` flag, 260, 286
`SAK` (secure attention key) function, 97
sample programs, obtaining, 12
`SA_SAMPLE_RANDOM` flag, 260, 286
`SA_SHIRQ` flag, 260, 278, 286
`/sbin/hotplug` utility, 398
sbull drivers
initialization, 468
request method, 475
sbull ioctl method, 473
sbull_request function, 469
SBus, 324
scatter/gather
DMA mappings, 450
I/O, 520
scatterlists
mapping, 450
structure, 462
`sched.h` header file, 40, 184
schedule function, 181
execution of code (delaying), 193
preventing endless loops with, 97
schedulers (I/O), 478
`schedule_timeout` function, 194
scheduling kernel timers, 196–202
scripts (hotplug), 403
SCSI
devices, 402
modules, 7
scull, 42, 47
char drivers, 70
concurrency (see concurrency)
design of, 42
device registration, 56
drivers (example), 80, 138

file operations, 49–53
inode structure, 55
locking (adding), 109
memory
troubleshooting, 107
usage, 60–63
next method, 87
open method, 58–59
pointers, 61
race conditions, 107
read method, 63–69
`read_proc` method, 85
readv calls, 69
release method, 59
semaphores, 112
show method, 88
stop method, 88
write method, 63–69
writev calls, 69
scull driver (example), 42
scullc driver (example), 219
`scull_cleanup` function, 179
`scull_getwritespaces` function, 158
scullp
example, 223
`mmap` implementations, 431
scullpipe devices (example), 153–162
scullsingle device, 174
sculluid code, 175
sculvy driver (example), 227, 233
searching PCI drivers, 326
sectors (size of), 470
`sector_t bi_sector` field (`bio` structure), 482
`sector_t capacity` field (`gendisk`), 467
`sector_t sector` field (request structure), 476
secure attention key (SAK) function, 97
security, 8
seeking devices, 171
select method, 163–169
poll method and, 51
semaphores, 109
completion, 114–116
implementation, 110–114
reader/writer, 113
unlocking, 110
sendfile system, 52
sendpage system, 52
`seq_file` interface, 87–90
seqlocks, 127
SEQNUM variable, 399
sequences (race conditions), 107

serial line configuration, 565
serial_icounter_struct structure, 566
set_bit operation, 126
set_config method, 512
setconsole program, 77
set_dma_addr function, 457
set_dma_count function, 457
set_dma_mode function, 457
set_mac_address method, 513
set_mb function, 238
set_multicast_list function, 539
set_multicast_list method, 510, 513
set_rmb function, 238
setterm program, 147
set_termios function, 560
set_wmb function, 238
sfile argument, 87
sg_dma_address function, 462
sg_dma_address macro, 451
sg_dma_len function, 462
sg_dma_len macro, 451
sharing
 code, 108
 interrupt handlers, 278–281
 queues, 207
short delays, 195–196
 sleeps, 196
short driver (example), 246
 accessing I/O memory, 252
 implementing interrupt handlers, 270
 installing interrupt handlers, 261
 probing, 266
short module, 265
shortpoint drivers, 282–286
show function, 386
show method
 kobjects, 373
 seq_file interface, 88
shutdown, 31, 362
shutting down modules (see unloading, modules)
SIGIO signal, 169
signal handling, 154
Simple Character Utility for Loading Localities
 (see scull)
Simple Hardware Operations and Raw Tests
 (see short driver)
simple sleeping, 149
single-open devices, 173
single-page streaming mappings, 450
SIOCDEVPRIVATE commands, 535
SIOCSIFADDR command, 535
SIOCSIFMAP command, 535
size
 data explicitly, 290
 explicit, 290
 kmalloc argument, 216
 pages, 292
 ports, 240
 of sectors, 470
skb_headlen function, 532
skb_headroom function, 531
skb_is_nonlinear functions, 532
skb_pull function, 532
skb_push function, 531
skb_put function, 531
skb_reserve function, 531
skb_tailroom function, 531
sk_buff structure
 fields for, 529
 transmitting packets, 516
skbuff.h header file, 516
SLAB_CACHE_DMA flag, 218
SLABCTOR_ATOMIc flag, 218
SLABCTOR_CONSTRUCTOR flag, 218
SLAB_HWCACHE_ALIGN flag, 218
SLAB_NO_REAP flag, 218
sleep_on function, 162
sleeps
 locking, 110
 manual, 156
 processes, 147–162
 short delays, 196
 spinlocks, 118
slow downs (avoiding), 82
slow interrupt handlers, 268
SMP (symmetric multiprocessor) systems, 21
snuffnet0 (IP number), 499
socket buffers, 516, 528–532
 allocation, 522
software
 loops, 195
 versions (see versions, numbering)
 (see also applications versus kernel modules)
software-mapped I/O memory (ioremap function), 250
SPARC architecture, 244
SPARC64 platform (data alignment), 294
special files, 43

spinlocks
 dma_spin_lock, 457
 hard_start_xmit function, 518
 releasing, 120
 xmit_lock function, 514
splitting kernels, 4–5
stacking modules, 28
standard C data types, 288
start method, 87
stat file, 263
state of request processing, 483
statements
 goto, 33
 printk (see printk function)
switch
 with ioctl method, 136
 return values, 140
static functions (locking), 121
static numbers, assignment of, 46
statistics
 on caches, 219
 on interrupts, 263
 on network drivers, 536
 on network interfaces, 504, 512, 536
status information, 514
stop method, 88, 512
store method (kobjects), 373
strace command, 91
strace tool, 162
streaming
 DMA mappings, 446, 448
 single-page mappings, 450
string operations, 241, 255
struct block_device_operations *fops field
 (gendisk), 467
struct bus_type *bus field, 382
struct cdev *i_cdev (inode structure field), 55
struct dentry *f_dentry (struct file field), 54
struct device fields, 381
struct device *parent field, 381
struct device_driver *driver field, 382
struct device_driver structure, 385
struct file, 53
struct file_operations *f_op (struct file field), 54
struct file_operations *fops variable
 (USB), 353
struct kobject kobj field, 381
struct module *owner function, 348
struct module *owner method, 50
struct net_device *next field (net_device structure), 506

struct pci_device_id structure (PCI), 309
struct request structure, 476
struct request_queue *queue field
 (gendisk), 467
struct scull_qset structure, 62
struct termios structure (tty drivers), 550–553
struct timeval pointer, 188
struct tty_flip_buffer structure, 559
struct urb structure, 336
struct usb_device *dev field (USB), 336
struct usb_device_id structure (USB), 346
struct usb_driver structure, 349
struct usb_host_interface *altsetting field
 (USB), 331
struct usb_host_interface *cur_altsetting field
 (USB), 332
struct usb_interface structure, 351
struct usb_iso_packet_descriptor
 iso_frame_desc field (USB), 341
structures
 bin_attribute, 374
 bio, 482, 487
 bus_type, 378
 cdev configuration, 56
 data, 49, 49–53
 devices, 383
 dev_mc_list, 538
 drivers, 386
 file_operations (mmap method and), 424
 gendisk, 467
 ifreq, 535
 kobjects, 364–371
 kset_hotplug_ops, 376
 ldd_driver, 386
 net_device, 502, 506–507
 net_device_stats, 505, 536
 registration, 55–57
 scatterlist, 462
 serial_icounter_struct, 566
 sk_buff, 529
 struct device_driver, 385
 struct request, 476
 struct scull_qset, 62
 struct termios (tty drivers), 550–553
 struct tty_flip_buffer, 559
 struct urb, 336
 struct usb_driver, 349
 struct usb_interface, 351
 tty_driver, 567
 tty_operations, 569
 tty_struct, 571

vm_area_struct, 420
vm_operations_struct, 421
submission of urbs, 344, 354
SUBSYSTEM variable, 399
subsystems, 368
classes, 391
deviceID register (PCI), 309
firmware, 407
ksets, 370
memory management, 4
module stacking, 29
USB (see USB)
vendorID register (PCI), 309
Super-H architecture, 244
supervisor mode, 20
support
 Ethtool, 541
 kernels (debugging), 73–75
 MII, 540
 multicasting, 538
 swappers, 193
switch statements
 return values, 140
 with ioctl method, 136
symbolic links (kobjects), 375
symbols, 28–29
 BLK_BOUNCE_HIGH, 480
 bytes, 300
 CHECKSUM, 523
 DMA_BIDIRECTIONAL, 448
 DMA_FROM_DEVICE, 448
 DMA_NONE, 448
 DMA_TO_DEVICE, 448, 461
 IFF_, 538
 NR_IRQS, 267
 PAGE_SIZE, 423
 PCI_DMA_FROMDEVICE, 449
 PCI_DMA_TODEVICE, 449
 PDEBUG/PDEBUGG, 80
 symbol table, 28–29
symmetric multiprocessor (SMP) systems, 21
synchronization
 DMA buffers, 452
 semaphores, 114
sysfs directory
 trees (USB), 333–335
 tty driver, 552
sysfs filesystem, 409
 low-level operations, 371–375
syslogd daemon, 79
sysrq operations, 98

sysrq.txt file, 97
sys_syslog function, 77
system calls, 25
system faults
 debugging, 93–98
 handling, 19
system hangs, 96–98
system shutdown, 362

T

_t data types, 291
table pages, 418
 I/O memory and, 249
 nopage VMA method, 427
tables, symbols, 28–29
tagged command queuing (TCQ), 492–493
tagged initialization formats, 53
tasklets, 202–204, 211
 interrupt handlers, 276
tasklet_schedule function, 276
tcpdump program, 501
TCQ (tagged command queueing), 492–493
tearing down single-page streaming
 mappings, 450
templates, scull (design of), 42
terminals, selecting for messages, 77
termios userspace functions, 560
test system setup, 15
test_and_change_bit operation, 127
test_and_clear_bit operations, 127
test_and_set_bit operation, 127
test_bit operation, 127
testing
 block drivers, 468
 char drivers, 70
 hello world modules, 17
 scullpipe drivers, 162
thread execution, 109
throughput (DMA), 440–459
time, 208
 boot (PCI), 306
 current time (retrieving), 188–190
 execution of code (delaying), 190–196,
 209
 HZ (time frequency), 183, 292
 intervals of (data type portability), 292
 kernel timers, 202
 lapses (measurement of), 183–188
 tasklets, 202–204
 time intervals in the kernel, 292
workqueues, 205–208

timeouts
 configuration, 193
 scheduling, 194
 transmission (see transmission timeouts)
timer.h header file, 198
timer_list structure, 198
timers, 202
 interrupts, 183
 kernels, 196–202, 210
timestamp counter (TSC), 186
tiny_close function, 556
tiny_tty_driver variable, 551
TIOCLINUX command, 77
tiocmget function, 562
tiocmset functions, 562
token ring networks, setting up interfaces
 for, 508
tools
 debuggers, 99–105
 Ethtool, 541
 kernels (enabling configuration
 options), 73–75
 lockmeter, 123
 /sbin/hotplug utility, 398
 strace, 162
 timers, 196–202
 (see also debugging; utilities)
top halves (interrupt handlers), 275–278
tracing programs, 105
tracking
 registration, 33
 struct scull_qset (structure), 62
transfers
 buffers, 448
 DMA, 440–459, 461
 USB without urbs, 356–359
transistor-transistor logic (TTL) levels, 245
transmission concurrency, controlling, 518
transmission of packets, 501, 516–520
transmission timeouts, 504, 519
 tx_timeout method and, 512
 watchdog_timeo field and, 514
traps (locking), 121–123
traversal of linked lists, 298
tr_configure function, 508
trees
 /dev, 403
 sysfs (USB and), 333–335
 tty drivers, 548
troubleshooting, 73
 caches, 237, 425, 445
 DMA hardware, 444

fragmentation, 442
locking, 121–123
memory (scull), 107
porting problems, 242
system hangs, 96
values, 295
 wrong font on console, 147
truncating devices on open, 59
TSC (timestamp counter), 186
TTL (transistor-transistor logic) levels, 245
tty drivers, 546–550
 buffers, 558
 directories, 566
 functions, 573
 line settings, 560–566
 pointers, 553–560
 struct termios, 550–553
 sysfs directories, 552
 tty_driver structure, 567
 tty_operations structure, 569
 tty_struct structure, 571
 tty_driver structure, 567, 569, 571
TTY_DRIVER_NO_DEVFS flag, 553
TTY_DRIVER_REAL_RAW flag, 553
TTY_DRIVER_RESET_TERMIOS flag, 552
tty_get_baud_rate function, 562
tty_register_driver function, 549
tunelp program, 3
turning messages on/off, 79
tx_timeout method, 512, 519
TYPE variable, 401
types
 addresses, 413
 bus_attribute, 380
 module parameter support, 36
 PCI driver support, 325

U

u16 bcdDevice_hi field (USB), 346
u16 bcdDevice_lo field (USB), 346
u16 idProduct field (USB), 346
u16 idVendor field (USB), 346
u16 match_flags field (USB), 346
u8 bDeviceClass field (USB), 347
u8 bDeviceProtocol field (USB), 347
u8 bDeviceSubClass field (USB), 347
u8 bInterfaceClass field (USB), 347
u8 bInterfaceProtocol field (USB), 347
u8 bInterfaceSubClass field (USB), 347
u8, u16, u32, u64 data types, 290
uaccess.h header file, 64, 72, 142, 180
udelay, 196

uint8_t/uint32_t types, 290
uintptr_t type (C99 standard), 289
unaligned data, 293
 access, 300
unaligned.h header file, 293
unidirectional pipes (USB endpoints), 329
uniprocessor systems, concurrency in, 21
universal serial bus (see USB)
Unix
 filesystems, 4
 interfaces (access to), 7
unlinking urbs, 345
unloading
 modules, 18, 25, 505
 USB drivers, 349
unlocking semaphores, 110
unmapping, DMA buffers, 449
 (see also mapping)
unregistering facilities, 33
unregister_netdev function, 505
unshielded twisted pair (UTP), 510
unsigned char *setup_packet field (USB), 338
unsigned int bi_size field (bio structure), 482
unsigned int f_flags (struct file field), 54
unsigned int irq function, 260
unsigned int pipe field (USB), 336
unsigned int transfer_flags field (USB), 337
unsigned long bi_flags field (bio
 structure), 482
unsigned long flags field (memory), 417
unsigned long flags function, 260
unsigned long method, 52
unsigned long nr_sectors field (request
 structure), 476
unsigned long pci_resource_end
 function, 317
unsigned long pci_resource_flags
 function, 317
unsigned long pci_resource_start
 function, 317
unsigned long state field (net_device
 structure), 506
unsigned num_altsetting field (USB), 332
unsigned short bio_hw_segments field (bio
 structure), 482
unsigned short bio_phys_segments field (bio
 structure), 482
unsigned type, 240
up function, 111
updates, RCU, 129
urandom device, 260

urbs
 cancellation of, 345
 interrupts, 342
 killing, 345
 submitting, 344
 unlinking, 345
 USB, 335–346
 creating/destroying, 341
 struct urb structure, 336
 submitting, 354
 transfers without, 356–359
urbs_completion function, 345
usage count, 426
 decremented by release method, 59
 incremented by open method, 58
 nopage method and, 432
USB request blocks (see urbs)
USB (universal serial bus), 7, 327–332
 configurations, 332
 hotplugging, 401
 stacking, 28
 sysfs directory tree, 333–335
 transfers without urbs, 356–359
 urbs, 335–346
 writing, 346–355
usb_alloc_urb function, 342
usb_bulk_msg function, 356
usb_control_msg function, 357
usbcore module, 28
USB_DEVICE macro, 347
USB_DEVICE_INFO macros, 347
USB_DEVICE_VER macro, 347
usb_fill_bulk_urb function, 343
usb_fill_control_urb function, 343
usb_fill_int_urb function, 342
usb_get_descriptor function, 358
USB_INTERFACE_INFO macro, 347
usb_kill_urb function, 345
usb_register_dev function, 352
usb_set_intfdata function, 351
usb_string function, 359
usb_submit_urb function, 344
usb_unlink_urb function, 345
user mode, 20
user programs, 3
user space, 19
 capabilities/restrictions in, 144
 communication with, 362
 direct I/O, 435–440
 explicitly sizing data in, 290
 I/O port access from, 241

user space (*continued*)
programming, 19, 37, 39
retrieving datum from, 143
transferring to/from kernel space, 63
tty drivers, 560–566
writing drivers in, 37
user virtual addresses, 413
User-Mode Linux, 104
utilities, 3
insmod, 17
modprobe, 25, 29
rmmod, 17
(see also programs)
utility fields (net_device structure), 514
UTP (unshielded twisted pair), 510
UTS_RELEASE macro, 27

V

values
BogoMips, 195
errors, 295
jiffies, 184, 514
loops_per_jiffy, 196
return
interrupt handlers, 272
switch statements, 140
variables
ACTION, 399
atomic, 124
char*name (USB), 352
console_loglevel, 77
DEVICE, 402
DEVPATH, 399
int minor_base (USB), 353
INTERFACE, 401
mode_t mode (USB), 353
NAME, 401
pci_bus_type, 392
PCI_CLASS, 400
PCI_ID, 400
PCI_SLOT_NAME, 400
PCI_SUBSYS_ID, 400
per-CPU, 228–230
PHYS, 401
PRODUCT, 401
SEQNUM, 399
struct file_operations *fops (USB), 353
SUBSYSTEM, 399
tiny_tty_driver, 551
TYPE, 401
vector operations, char drivers, 69
vendorID register (PCI), 309

VERIFY_SYMBOLS, 142, 180
version dependency, 26
version.h header file, 26, 40
versions
dependency, 26
numbering, 10–11
char drivers, 43
major device numbers, 44
minor device numbers, 44
older char device registration, 57
VESA Local Bus (VLB), 323
vfree function, 225
video memory (mapping), 423
viewing kernels, 5
virt_to_page function, 417
virtual addresses, 414
conversion, 444
remapping, 434
(see also addresses)
virtual memory, 413
(see also memory)
virtual memory area (see VMA)
VLB (VESA Local Bus), 323
VMA (virtual memory area), 419–422, 426
vmalloc allocation function, 224–228
vmalloc.h header file, 225
vm_area_struct structure, 420
VM_IO flag, 421
vm_operations_struct structure, 421
VM_RESERVED flag, 421
void barrier function, 237
void blk_queue_bounce_limit function, 480
void blk_queue_dma_alignment
function, 481
void blk_queue_hardsect_size function, 481
void blk_queue_max_hw_segments
function, 480
void blk_queue_max_phys_segments
function, 480
void blk_queue_max_sectors function, 480
void blk_queue_max_segment_size
function, 480
void blk_start_queue function, 480
void blk_stop_queue function, 480
void *context field (USB), 339
void *dev_id function, 260
void *driver_data field, 382
void field (PCI registration), 312
void function, 348
void mb function, 237
void *private_data field (gendisk), 467
void *private_data (struct file field), 54

void read_barrier_depends function, 237
void *release field, 382
void rmb function, 237
void smp_mb functions, 238
void smp_read_barrier_depends function, 238
void smp_rmb function, 238
void smp_wmb function, 238
void tasklet_disable function, 204
void tasklet_disable_nosync function, 204
void tasklet_enable function, 204
void tasklet_hi_schedule function, 204
void tasklet_kill function, 204
void tasklet_schedule function, 204
void *transfer_buffer field (USB), 338
void *virtual field (memory), 417
void wmb function, 237

W

wait queues, 149, 156, 181
 delaying code execution, 194
 poll table entries and, 167
 putting processes into, 182
wait_event macro, 149
wait_event_interruptible_timeout function, 194
wake_up function, 150, 159, 181
wake_up_interruptible function, 181
wake_up_interruptible_sync function, 181
wake_up_sync function, 181
Wall flag, 291
watchdog_timeo field (net_device structure), 514, 519
wc command, 92
wMaxPacketSize field (USB), 331
workqueues, 205–208, 211
 interrupt handlers, 277

WQ_FLAG_EXCLUSIVE flag set, 160
write function (tty drivers), 556
write method, 50, 63–69
 code for, 68
 configuring DMA controller, 456
 f_pos field (file structure) and, 54
 oops messages, 94
 poll method and, 166
 return values, rules for interpreting, 68
 select method and, 166
 strace command and, 92
write system, 50
write-buffering example, 282
writev calls, 69
writev method, 52
writing, 73
 blocking/nonblocking operations, 151
 control sequences to devices, 146
 to a device, 63–66, 68
drivers
 in user space, 37
 role of, 2–4
 version numbering, 10
UBS drivers, 346–355

X

x86 architecture
 interrupt handling on, 268
 porting and, 243
xmit_lock function, 514
xtime variable, 189

Z

zero-order limitations, 432
zones (memory), 215
zSeries architecture, 402



,ldr3IX.fm.14814 Page 616 Thursday, January 27, 2005 12:29 PM

