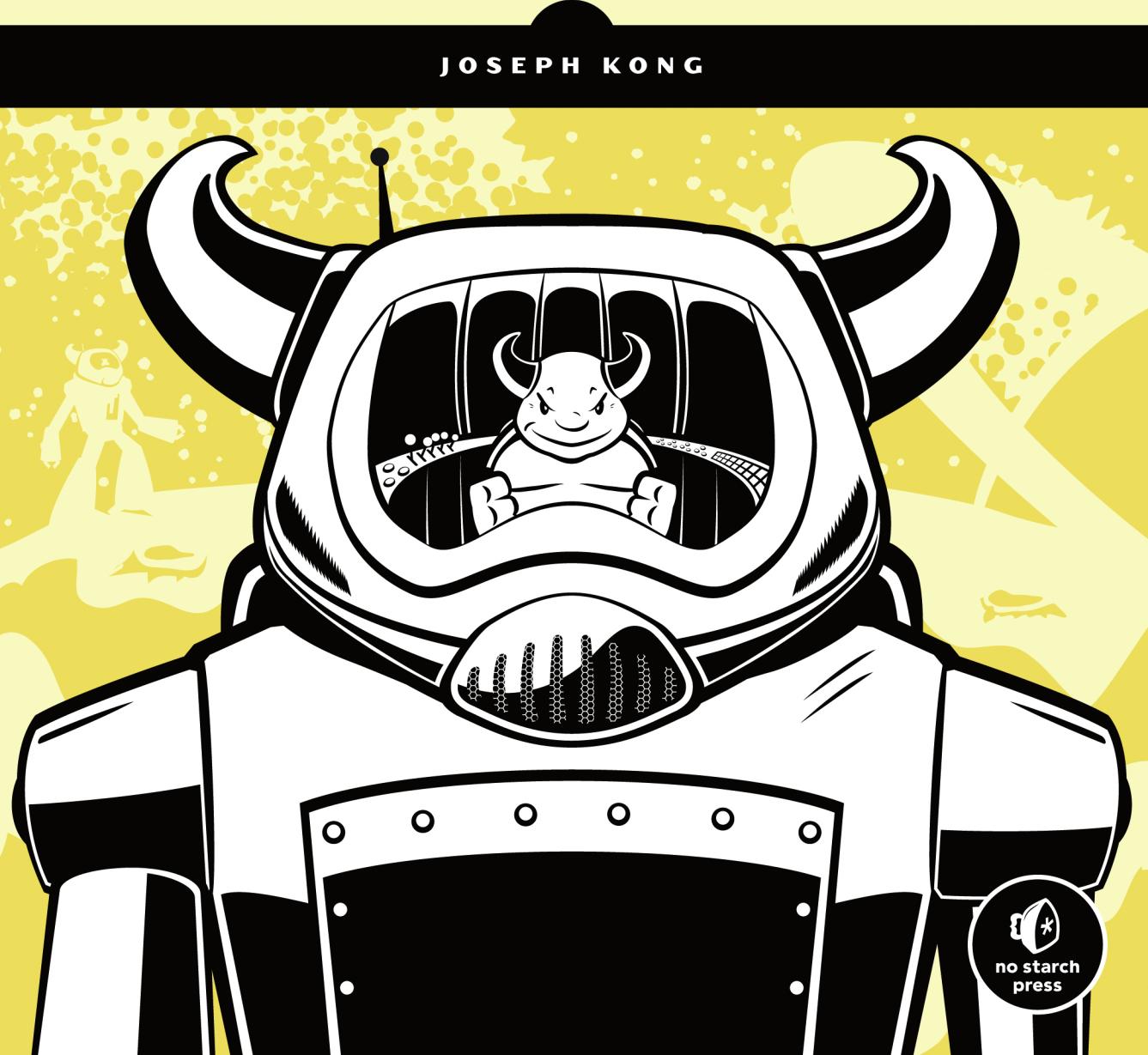


FREEBSD® DEVICE DRIVERS

A GUIDE FOR THE INTREPID

JOSEPH KONG



INDEX

Numbers

00–04 bit, 291
05–07 bit, 291
08–15 bit, 291
o constant, 95
0xFFFFFFFF, 197
16–18 bit, 291
19 bit, 291
20–27 bit, 291
28–31 bit, 291

A

access argument, 46
`acpi_sleep_event` event handler, 92
`acpi_wakeup_event` event handler, 92
action routines
 `XPT_GET_TRAN_SETTINGS` constant, 246–249
 `XPT_PATH_INQ` constant, 243–245
 `XPT_RESET_BUS` constant, 245–246
 `XPT_RESET_DEV` constant, 255
 `XPT_SCSI_IO` constant, 250–255
 `XPT_SET_TRAN_SETTINGS` constant, 249
Advanced Technology Attachment Packet Interface (ATAPI), 226
`ahc_action` function, 227
`ahc_done` function, 227, 240
alignment argument, 23, 197
alternate setting, 258
arg argument, 46, 116
`at45d_attach` function, 217–218
`at45d_delayed_attach` function, 218–219
`at45d_get_info` function, 219–220
`at45d_get_status` function, 220–221
`at45d_strategy` function, 221
`at45d_task` function, 221–223
ATAPI (Advanced Technology Attachment Packet Interface), 226
`atomic_add_int` function, 106
autoconfiguration. *See* Newbus drivers

B

`biodone` function, 223
`biofinish` function, 223
`bio_pblkno` variable, 222
`bioq_flush` function, 213
`bioq_insert_head` function, 212
`bioq_insert_tail` function, 212
`bioq_remove` function, 213
`bio` structure, 210
`bits_per_char` function, 111–112
block, defined, 207
block-centric I/O requests, 222
block devices, 2
block drivers, 15–16
block I/O queues, 212–213
block I/O structures, 210–211
boundary argument, 23, 197
`<bsd.kmod.mk>` Makefile, 6
`bt.c` source file, 255
buffers, DMA, 195
 `bus_dmamap_load` function, 200–201
 `bus_dmamap_load_mbuf` function, 201
 `bus_dmamap_load_mbuf_sg` function, 201–202
 `bus_dmamap_load_uio` function, 202
 `bus_dmamap_unload` function, 202
 `bus_dma_segment` structures, 199–200
buflen argument, 200
bufsize field, 260
bulk endpoints, 258
 `bus_alloc_resource` function, 123, 166
 `bus_deactivate_resource` function, 124
 `BUS_DMA_ALLOCNOW` constant, 198
 `BUS_DMA_COHERENT` constant, 199, 203
 `bus_dmamap_create` function, 195, 199
 `bus_dmamap_destroy` function, 199
 `bus_dmamap_load` function, 195, 200–201
 `bus_dmamap_load_mbuf` function, 201
 `bus_dmamap_load_mbuf_sg` function, 201–202
 `bus_dmamap_load_uio` function, 202
 `bus_dmamap_unload` function, 202

bus_dmamem_alloc function, 202, 205
 bus_dmamem_free function, 203
 BUS_DMA_NOCACHE constant, 172, 201, 203
 BUS_DMA_NOWAIT constant, 201, 203
 bus_dma_segment structures, 199–200
 BUS_DMASYNC_POSTREAD constant, 205
 BUS_DMASYNC_PREWRITE constant, 205
 bus_dma_tag_create function, 195
 bus_dma_tag_destroy function, 198
 BUS_DMA_WAITOK constant, 203
 BUS_DMA_ZERO constant, 203
 busname argument, 116
 BUS_PROBE_SPECIFIC success code, 133
 bus_read_*N* functions, 167
 bus_release_resource function, 124
 bus_setup_intr function, 126
 BUS_SPACE_BARRIER_READ constant, 172
 BUS_SPACE_BARRIER_WRITE constant, 172
 BUS_SPACE_MAXADDR constant, 197
 bus_teardown_intr function, 126
 bus_write_multi_*N* functions, 169
 bus_write_*N* functions, 169
 bus_write_region_*N* functions, 169

C

callback2 argument, 201
 callback2 function, 201
 callbackarg argument, 200
 callback argument, 200
 callback field, 260
 callout_drain function, 96
 callout_init_mtx function, 95
 callout_init function, 94
 CALLOUT_MPSAFE constant, 95
 callout_reset function, 96
 CALLOUT_RETURNUNLOCKED constant, 95
 callouts, 94–98
 callout_schedule function, 96
 CALLOUT_SHAREDLOCK constant, 95
 callout_stop function, 95
 CAM (Common Access Method) standard
 action routines
 XPT_GET_TRAN_SETTINGS constant, 246–249
 XPT_PATH_INQ constant, 243–245
 XPT_RESET_BUS constant, 245–246
 XPT_RESET_DEV constant, 255
 XPT_SCSI_IO constant, 250–255
 XPT_SET_TRAN_SETTINGS constant, 249
 HBA (host bus adapter) driver example
 mfip_action function, 236–238
 mfip_attach function, 234–235
 mfip_detach function, 235–236
 mfip_done function, 240–241

mfip_poll function, 238
 mfip_start function, 238–240
 overview, 225–227
 SIM registration routines
 cam_sim_alloc function, 242–243
 cam_simq_alloc function, 242
 xpt_bus_register function, 243
 CAM Control Block (CCB), 227
 camisr function, 227
 cam_sim_alloc function, 235, 242–243
 cam_simq_alloc function, 242
 CCB (CAM Control Block), 227
 ccb_h.func_code variable, 238
 ccb_pathinq structure, 243, 245
 ccb_scsio structure, 253
 ccb_trans_settings structure, 249
 chan argument, 84
 change_callback argument, 290
 character devices, 2
 character drivers
 character device switch table, 8
 destroy_dev function, 9
 DEV_MODULE macro, 15
 d_foo function, 7–8
 echo_modevent function, 14
 echo_read function, 13–14
 echo_write function, 12–13
 loading, 15
 make_dev function, 9
 ciss_setup_msix function, 294–295
 commands for ioctl interface, 29–30
 Common Access Method (CAM) standard. *See* CAM standard
 compiling KLDs, 6–7
 condition variables, 79–81
 configurations, 259
 configuration structures for USB drivers
 management routines for, 264–265
 mandatory fields, 260
 optional fields, 260–261
 transfer flags, 261–262
 contexts for sysctl interface, 44
 contigfree function, 22, 23
 contigmalloc function, 22–25
 contiguous physical memory, 22–25
 control endpoints, 258
 cookiep argument, 126
 count argument, 123
 count value, 54
 ctx argument, 46
 cv_broadcastpri function, 81
 cv_destroy function, 81
 cv_init function, 81
 cv_timedwait function, 81
 cv_timedwait_sig function, 81

cv_wait_sig function, 81
 cv_wait_unlock function, 81
 cv_wmesg function, 81

D

d (descriptor) argument, 38
 dadone function, 227
 dasstart function, 227
 dastrategy function, 226
 data argument, 4
 Data Carrier Detect (DCD), 107
 data transfers for USB drivers, 262–264
 d_close field, 209
 d_close function, 57
 d_drv1 field, 210
 debug.sleep.test sysctl, 90–92
 DECLARE_MODULE macro
 data argument, 4
 name argument, 4
 order argument, 4–5
 sub argument, 4
 delaying execution
 callouts, 94–96
 event handlers for, 92–94
 load function, 89–90
 sleeping, 83–85
 sleep_modevent function, 88–89
 sleep_thread function, 90–91
 sysctl_debug_sleep_test function, 91
 taskqueues
 global, 97
 management routines for, 97–98
 overview, 96–97
 unload function, 91–92
 voluntary context switching, 83–85
 descr argument, 46
 descriptive fields for disk structures, 208–209
 descriptor (d argument), 38
 destroy_dev function, 9, 72
 destroying tags for DMA, 198–199
 devclass argument, 116
 dev_clone event handler, 92, 103
 DEV_MODULE macro, 15
 device_attach function, 114
 device_detach function, 114, 115
 device_foo functions, 114–115
 device_identify function, 114
 device method table, 115
 device_probe function, 114
 device_resume function, 114
 devices
 configuration of, 259
 defined, 1
 driver types, 1–2

device_shutdown function, 114
 device_suspend function, 114
 d_flags field, 209
 d_foo function, 7–8, 72, 121
 d_fwheads field, 209
 d_fwsectors field, 209
 d_ident field, 209
 d_ioctl field, 209
 d_ioctl function, 28, 58
 direction field, 260
 Direct Memory Access (DMA). *See* DMA
 DISKFLAG_CANDELETE constant, 208
 DISKFLAG_CANFLUSHCACHE constant, 208
 DISKFLAG_NEEDSGIANT constant, 208
 disk structures
 descriptive fields, 208–209
 driver private data, 210
 management routines for, 210
 mandatory media properties, 209
 optional media properties, 209
 storage device methods, 209
 dismantling transfers using DMA, 196
 DMA (Direct Memory Access)
 buffers
 bus_dmamap_load_mbuf_sg function, 201–202
 bus_dmamap_load_mbuf function, 201
 bus_dmamap_load_uio function, 202
 bus_dmamap_load function, 200–201
 bus_dmamap_unload function, 202
 bus_dma_segment structures, 199–200
 synchronizing, 205
 example using, 203–205
 maps, 199, 202–203
 overview, 193
 tags for
 creating, 197–198
 destroying, 198–199
 transfers using
 dismantling, 196
 initiating, 196
 dmat argument, 198, 200, 205
 d_maxsize field, 209
 d_mediasize field, 209
 dontcare_mask argument, 289
 d_open field, 209
 d_open function, 57
 driver argument, 116
 DRIVER_MODULE macro
 arg argument, 116
 busname argument, 116
 devclass argument, 116
 driver argument, 116
 evh argument, 116
 name argument, 116

driver private data, 210

`ds_addr` field, 200

`d_sectorsize` field, 209

`d_strategy` field, 209

`d_stripesize` field, 209

dump routines, 209

dynamic node, 47

dynamic sysctl, 44–47

E

`%eax` value, 54

`ECHO_CLEAR_BUFFER` command, 33

`echo_ioctl` function, 36

`echo_modevent` function, 14, 36–37

`echo_read` function, 13–14

`ECHO_SET_BUFFER_SIZE` command, 33

`echo_set_buffer_size` function, 35

`echo_write` function, 12–13, 34–35

ECP (Extended Capabilities Port)

mode, 156

`em(4)` driver, 299

`em_handle_rx` function, 303

`em_rxeof` function, 300–303

`em_start_locked` function, 304–305

`em_txeof` function, 305–307

`em_xmit` function, 305

`end` argument, 123

end of packet (`eop`), 301

endpoint, 258

endpoint field, 260

Enhanced Parallel Port (EPP), 156

`ENXIO` error code, 134

`eop` (end of packet), 301

`ep_index` field, 261

EPP (Enhanced Parallel Port), 156

`ether_ifattach` function, 287–288

`ether_ifdetach` function, 288

`EVENTHANDLER_DEREGISTER` macro, 93

`EVENTHANDLER_INVOKE` macro, 94

`EVENTHANDLER_PRI_ANY` constant, 93

`EVENTHANDLER_REGISTER` macro, 93

event handlers, 92–94, 98

`evh` argument, 116

exclusive holds, 73

`ext_buffer` flag, 262

Extended Capabilities Port (ECP)

mode, 156

Extended Message Signaled Interrupts
(MSI-X), 294

extended mode, 156

F

Fibre Channel (FC), 226

filter argument, 126

`FILTER_HANDLED` constant, 127

filter routine, 126

`FILTER_SCHEDULE_THREAD` constant, 127

`FILTER_STRAV` constant, 127

`filtfuncarg` argument, 197

`filtfunc` argument, 197

`filtfunc` function, 197

FireWire (IEEE 1394), 226

flags argument, 18–19, 126, 198–201

flags field, 261

flash memory driver example

`at45d_attach` function, 217–218

`at45d_delayed_attach` function, 218–219

`at45d_get_info` function, 219–220

`at45d_get_status` function, 220–221

`at45d_strategy` function, 221

`at45d_task` function, 221–223

foo bytes, 279

`foo_callback` function, 201

foo lock, 65

`foo_pci_attach` function, 120–121

`foo_pci_detach` function, 121–122

`foo_pci_probe` function, 120

`force_short_xfer` flag, 262

format argument, 46

frames field, 261

free function, 18

G

`g` (group) argument, 29

global taskqueues, 97

H

handler argument, 46

hardware resource management with
Newbus drivers, 122–124

HBA (host bus adapter) driver

`mfip_action` function, 236–238

`mfip_attach` function, 234–235

`mfip_detach` function, 235–236

`mfip_done` function, 240–241

`mfip_poll` function, 238

`mfip_start` function, 238–240

Hello, world! KLD, 5–6

`highaddr` argument, 197

host bus adapter (HBA) driver. *See HBA*
driver

I

- IEEE 1394 (FireWire), 226
- if* structures, 291
- ifaddr_event event handler, 93
- *ifattach function, 285
- if_clone_event event handler, 93
- if_index field, 261
- if_init field, 285
- if_initname function, 287
- if_input field, 285
- if_ioctl field, 285
- ifmedia_add function, 290
- ifmedia_removeall function, 291
- ifmedia_set function, 291
- ifmedia structure, 289
- IFM_GMASK mask, 291
- IFM_IMASK mask, 291
- IFM_MMASK mask, 291
- IFM_NMASK mask, 291
- IFM_OMASK mask, 291
- IFM_TMASK mask, 291
- ifnet_arrival_event event handler, 93
- ifnet_departure_event event handler, 93
- ifnet structure, 283, 286–287
- if_output field, 285–286
- if_qflush field, 286
- if_reassign field, 286
- if_resolvemulti field, 286
- if_start field, 286
- if_transmit field, 286
- if_watchdog field, 286
- implementing MSI, 294–296
- initiating transfers using DMA, 196
- init routines, 285
- input/output (I/O) operations. *See also* I/O operations
- input routine, 285
- Intelligent Platform Management Interface (IPMI) driver. *See* IPMI driver
- Intel PCI Gigabit Ethernet adapter driver, 291–293
- interfaces, 7, 258, 283
- interrupt, defined, 125
- interrupt endpoints, 258
- interrupt handlers
 - examples of
 - pint_attach function, 133–134
 - pint_close function, 135–136
 - pint_detach function, 134
 - pint_identify function, 132
 - pint_intr function, 137–138
 - pint_open function, 134–135
 - pint_probe function, 132–133
 - pint_read function, 136–137
 - pint_write function, 136
- overview, 125, 126–127
- on parallel port, 138–139
- registering, 125–126
- interrupt-request lines (IRQs), 122
- interval field, 261
- INTR_ENTROPY constant, 126
- INTR_MPSAFE constant, 126
- INVARIANTS option, 18
- I/O (input/output) operations. *See also* MMIO; PMIO
- ioctl interface
 - commands for, 29–30
 - echo_ioctl function, 36
 - echo_modevent function, 36–37
 - echo_set_buffer_size function, 35
 - echo_write function, 34–35
 - invoking, 37–40
- sysctl interface
 - contexts for, 44
 - dynamic sysctl, 44–47
 - overview, 40–44
 - SYSCTL_CHILDREN macro, 47
 - sysctl_set_buffer_size function, 50–52
 - SYSCTL_STATIC_CHILDREN macro, 47
- ioctl commands, 28
- ioctl interface
 - commands for, 29–30
 - echo_ioctl function, 36
 - echo_modevent function, 36–37
 - echo_set_buffer_size function, 35
 - echo_write function, 34–35
 - invoking, 37–40
- _IO macro, 29
- i-Opener LEDs driver
 - led_attach function, 178
 - led_close function, 180
 - led_detach function, 178–179
 - led_identify function, 177
 - led_open function, 179
 - led_probe function, 177–178
 - led_read function, 180–181
 - led_write function, 181–182
- _IOR macro, 29
- _IOW macro, 29
- _IOWR macro, 29
- IPMI (Intelligent Platform Management Interface) driver
 - ipmi2_pci_attach function, 189–191
 - ipmi2_pci_probe function, 189
 - ipmi_pci_attach function, 187–189

IPMI driver, *continued*
 `ipmi_pci_match` function, 186
 `ipmi_pci_probe` function, 185–186
 `ipmi2_pci_attach` function, 189–191
 `ipmi2_pci_probe` function, 189
 `ipmi_attached` variable, 186
 `ipmi_identifiers` array, 186
 `ipmi_pci_attach` function, 187–189
 `ipmi_pci_match` function, 186
 `ipmi_pci_probe` function, 185–186
 IRQs (interrupt-request lines), 122
 isochronous endpoints, 258
 ithread argument, 126
 ithread routine, 127

K

Keyboard Controller Style (KCS)
 mode, 188
KLDs (loadable kernel modules)
 block drivers, 15–16
 character drivers
 character device switch table, 8
 `destroy_dev` function, 9
 `DEV_MODULE` macro, 15
 `d_foo` function, 7–8
 `echo_modevent` function, 14
 `echo_read` function, 13–14
 `echo_write` function, 12–13
 loading, 15
 `make_dev` function, 9
 compiling and loading, 6–7
 `DECLARE_MODULE` macro
 `data` argument, 4
 `name` argument, 4
 `order` argument, 4–5
 `sub` argument, 4
Hello, world! example, 5–6
module event handlers, 2–3
`kldunload -f` command, 61

L

LED driver
 `led_attach` function, 178
 `led_close` function, 180
 `led_detach` function, 178–179
 `led_identify` function, 177
 `led_open` function, 179
 `led_probe` function, 177–178
 `led_read` function, 180–181
 `led_write` function, 181–182
len argument, 46
loadable kernel modules (KLDs). *See KLDs*

load function, 89–90
loading
 character drivers, 15
 KLDs, 6–7
lockfuncarg argument, 198
lockfunc argument, 198
locks, 65
longdesc argument, 19
lowaddr argument, 197
LP_BUSY flag, 157
LP_BYPASS flag, 156
lpt_attach function, 148–150
lpt_close function, 159–160
lptcontrol(8) utility, 162
lpt_detach function, 150
lpt_detect function, 147–148
lpt_identify function, 146
lpt_intr function, 156–157
lpt_ioctl function, 160–162
lpt_open function, 151–153
lpt_port_test function, 147, 148
lpt_probe function, 146
lpt_push_bytes function, 158–159
lpt_read function, 153–154
lpt_release_ppbus function, 162–163
lpt_request_ppbus function, 162
lpt_timeout function, 158
lpt_write function, 154–156

M

`make_dev` function, 9
Makefiles, 6
`MALLOC_DECLARE` macro, 20
`MALLOC_DEFINE` macro, 19
`malloc` function, 18
`malloc_type` structures
 `MALLOC_DECLARE` macro, 20
 `MALLOC_DEFINE` macro, 19
management routines
 for condition variables, 80–81
 for disk structures, 210
 for DMA maps, 199, 202–203
 for MSI (Message Signaled
 Interrupts), 297
 for mutex locks, 66–68
 for network interface media structures,
 289–291
 for network interface structures,
 286–288
 for rw (reader/writer) locks, 78–79
 for sx (shared/exclusive) locks, 73–75
 for taskqueues, 97–98

mandatory fields for USB drivers, 260
 mandatory media properties for disk structures, 209
`manual_status` flag, 262
 maps, DMA, 199, 202–203
 masks, for ignoring bits, 291
`max_dev_transactions` argument, 242, 243
`MAX_EVENT` constant, 88
`maxsegsz` argument, 198
`maxsize` argument, 198
`max_tagged_dev_transactions` argument, 243
`mbuf` argument, 201
`mbuf` chain, 293
`mbuf` structures, 293–294
`M_ECHO` structure, 22
 media properties for disk structures
 mandatory, 209
 optional, 209
 memory allocation
 contiguous physical memory, 22–25
`malloc_type` structures
 `MALLOC_DECLARE` macro, 20
 `MALLOC_DEFINE` macro, 19
 overview, 17–19
 memory barriers, 172
 memory-mapped I/O (MMIO). *See* MMIO
 Message Signaled Interrupts (MSI), 294
 implementing, 294–296
 management routines for, 297
 methods structure for USB drivers, 265
`mfi(4)` code base, 241
`mfi_intx` function, 240
`mfiip_action` function, 236–238
`mfiip_attach` function, 234–235
`mfiip_detach` function, 235–236
`mfiip_done` function, 240–241
`mfiip_poll` function, 238
`mfiip_start` function, 238–240
`mfi_startio` function, 239, 252
 MMIO (memory-mapped I/O). *See also*
 I/O operations; PMIO
 and memory barriers, 172
 reading from, 166–167
 stream operations, 169–172
 writing to, 167–169
`M_NOWAIT` constant, 19, 23
 modem drivers. *See* virtual null modem
`modeventtype_t` argument, 3
`MOD QUIESCE` constant, 61
 module event handlers, 2–3
 MSI (Message Signaled Interrupts), 294
 implementing, 294–296
 management routines for, 297
 MSI message, 294
 MSI-X (Extended Message Signaled Interrupts), 294
 MSI-X message, 294
`msleep_spin` function, 85
`MTX_DEF` constant, 67
`mtx_destroy` function, 68
`MTX_DUPOK` constant, 67
`mtx_init` function, 67
`MTX_NOPROFILE` constant, 67
`MTX_NOWITNESS` constant, 67
`MTX_QUIET` constant, 67
`MTX_RECURSE` constant, 67
`MTX_SPIN` constant, 67
`mtx_trylock` function, 68
`mtx_unlock_spin` function, 68
 mutex locks
 management routines for, 66–68
`race_modevent` function, 71–72
 sleep mutexes, 66
 spin mutexes, 65–66
`M_WAITOK` constant, 19, 23
`mword` value, 290–291
`M_ZERO` constant, 19, 23

N

`name` argument
 for `DECLARE_MODULE` macro, 4
 description of, 46
 for `DRIVER_MODULE` macro, 116
`n` argument, 30
 network devices, 2
 network drivers
 example of, 291–293
 `mbuf` structures, 293–294
 MSI (Message Signaled Interrupts), 294
 implementing, 294–296
 management routines for, 297
 network interface media structures,
 289–291
 network interface structures
 `ether_ifattach` function, 287–288
 `ether_ifdetach` function, 288
 management routines for, 286–288
 packets.
 post transmitting, 307–308
 receiving, 299–303
 transmitting, 304–307
 network interface media structures,
 289–291
 network interface structures
 `ether_ifattach` function, 287–288
 `ether_ifdetach` function, 288
 management routines for, 286–288

- Newbus drivers
- `device_foo` functions, 114–115
 - `device` method table, 115
 - `DRIVER_MODULE` macro
 - `arg` argument, 116
 - `busname` argument, 116
 - `devclass` argument, 116
 - `driver` argument, 116
 - `evh` argument, 116
 - `name` argument, 116
 - example of
 - `d_foo` functions, 121
 - `foo_pci_attach` function, 120–121
 - `foo_pci_detach` function, 121–122
 - `foo_pci_probe` function, 120
 - loading, 122
 - hardware resource management with, 122–124
 - overview, 113–114
- nibble mode, 154
- `nmdm(4)` driver, 99–100, 102
- `nmdm_alloc` function, 105–106
- `nmdm_clone` function, 104
- `nmdm_count` variable, 103
- `nmdm_inwakeup` function, 108
- `nmdm_modem` function, 108–109
- `nmdm_modevent` function, 103
- `nmdm_outwakeup` function, 106
- `nmdm_param` function, 109–110
- `nmdm_task_tty` function, 106–107
- `nmdm_timeout` function, 110, 111
- `no_pipe_ok` flag, 262
- `np_rate` variable, 110
- `nsegments` argument, 198
- `ns_part` variables, 106
- `number` argument, 46
- ## O
- optional fields for USB drivers, 260–261
- optional media properties for disk structures, 209
- `order` argument, 4–5
- output routines, 285–286
- ## P
- packets
- post transmitting, 307–308
 - receiving
 - `em_handle_rx` function, 303
 - `em_rxeof` function, 300–303
 - transmitting
 - `em_start_locked` function, 304–305
 - `em_txeof` function, 305–307
- parallel port
- interrupt handlers on, 138–139
 - printer driver example
 - `lpt_attach` function, 148–150
 - `lpt_close` function, 159–160
 - `lpt_detach` function, 150
 - `lpt_detect` function, 147–148
 - `lpt_identify` function, 146
 - `lpt_intr` function, 156–157
 - `lpt_ioctl` function, 160–162
 - `lpt_open` function, 151–153
 - `lpt_port_test` function, 148
 - `lpt_probe` function, 146
 - `lpt_push_bytes` function, 158–159
 - `lpt_read` function, 153–154
 - `lpt_release_ppbus` function, 162–163
 - `lpt_request_ppbus` function, 162
 - `lpt_timeout` function, 158
 - `lpt_write` function, 154–156
 - parent argument, 46, 197
 - `pause` function, 85
 - `pci_alloc_msi` function, 297
 - `pci_alloc_msix` function, 297
 - `pci_msi_count` function, 297
 - `pci_msix_count` function, 297
 - `PCIR_BAR(x)` macro, 189
 - `pci_release_msi` function, 297
 - `_pcsid` structures, 120
 - physical memory, contiguous, 22–25
 - `pint_attach` function, 133–134
 - `pint_close` function, 135–136
 - `pint_detach` function, 134
 - `pint_identify` function, 132
 - `pint_intr` function, 137–138
 - `pint_open` function, 134–135
 - `pint_probe` function, 132–133
 - `pint_read` function, 136–137
 - `pint_write` function, 136
 - pipe, defined, 257
 - `pipe_bof` flag, 262
 - PMIO (port-mapped I/O). *See also* I/O operations; MMIO
 - i-Opener LEDs driver example
 - `led_attach` function, 178
 - `led_close` function, 180
 - `led_detach` function, 178–179
 - `led_identify` function, 177
 - `led_open` function, 179
 - `led_probe` function, 177–178
 - `led_read` function, 180–181
 - `led_write` function, 181–182
 - and memory barriers, 172
 - reading from, 166–167
 - stream operations, 169–172
 - writing to, 167–169

poll routines, 238
 port-mapped I/O (PMIO). *See* PMIO
 power_profile_change event handler, 93
 ppb_release_bus function, 136
 ppb_sleep function, 137
 printer driver
 ulpt_close function, 276
 ulpt_detach function, 273
 ulpt_ioctl function, 276
 ulpt_open function, 273–274
 ulpt_probe function, 270–273
 ulpt_read_callback function, 280–281
 ulpt_reset function, 274
 ulpt_start_read function, 277
 ulpt_start_write function, 278
 ulpt_status_callback function, 281–282
 ulpt_stop_read function, 278
 ulpt_stop_write function, 278
 ulpt_watchdog function, 277
 ulpt_write_callback function, 279–280
 unlpt_open function, 275–276
 priority argument, 84
 process_exec event handler, 93
 process_exit event handler, 93
 process_fork event handler, 93
 proxy_buffer flag, 262
 pseudocode, 194–195
 pseudo-devices, 2

Q

qflush routines, 286

R

race conditions, 65
 race_destroy function, 59
 race_find function, 58–59
 RACE_IOC_ATTACH operation, 60
 RACE_IOC_DETACH operation, 60
 RACE_IOC_LIST operation, 60
 RACE_IOC_QUERY operation, 60
 race_ioctl function, 59–61, 70
 race_ioctl.h header, 57
 race_ioctl_mtx function, 70
 race_modevent function, 60–61, 71–72
 race_new function, 58
 race_softc structure, 57, 58, 59, 64
 r argument, 126
 readers, defined, 78
 reader/writer (rw) locks, 78–79
 reading
 from MMIO (memory-mapped I/O),
 166–167
 from PMIO (port-mapped I/O), 166–167

read operations, 29
 reallocf function, 18
 realloc function, 18
 reassign routines, 286
 receiving packets
 em_handle_rx function, 303
 em_rxeof function, 300–303
 overview, 299–300
 recursing on exclusive locks, avoiding, 81
 registering interrupt handlers, 125–126
 resolvemulti routines, 286
 RF_ACTIVE constant, 123
 RF_ALLOCATED constant, 123
 RF_SHAREABLE constant, 123
 RFSTOPPED constant, 90
 RF_TIMESHARE constant, 123
 rid argument, 123
 rw (reader/writer) locks, 78–79
 rw_destroy function, 79
 rw_init_flags function, 79
 rw_init function, 79
 rw_runlock function, 79
 rw_try_rlock function, 79
 rw_try_wlock function, 79
 rw_wunlock function, 79

S

scatter/gather segment, 198
 sc_open_mask value, 179
 sc_open_mask variable, 178
 sc_read_mask variable, 178
 sc->sc_state value, 135–136, 152
 SCSI Parallel Interface (SPI), 226
 Server Management Interface Chip
 (SMIC) mode, 188
 shared/exclusive (sx) locks. *See* sx locks
 shared holds, 73
 shortdesc argument, 19
 short_frames_ok flag, 262
 short_xfer_ok flag, 262
 shutdown_final event handler, 92, 93
 shutdown_post_sync event handler, 93
 shutdown_pre_sync event handler, 93
 sigoff argument, 109
 sigon argument, 109
 SIM queues, 235
 SIM registration routines for CAM
 (Common Access Method)
 cam_sim_alloc function, 242–243
 cam_simq_alloc function, 242
 xpt_bus_register function, 243
 SIMs (software interface modules), 225
 size argument, 18
 *sleep function, 66

sleeping, 66, 83–85, 98
`sleep_modevent` function, 88–89
sleep mutexes, 66
`sleep_thread` function, 90–91
SMBIOS (System Management BIOS), 188
SMIC (Server Management Interface Chip) mode, 188
software interface modules (SIMs), 225
SPI (SCSI Parallel Interface), 226
`spi_command` structure, 220, 223
spin, defined, 65
spin mutexes, 65–66
`stall_pipe` flag, 262
start argument, 123
start routines, 286
static node, 47
`status_callback` argument, 290
storage device methods for disk structures, 209
storage drivers
 block I/O queues, 212–213
 block I/O structures, 210–211
 disk structures
 descriptive fields, 208–209
 driver private data, 210
 management routines for, 210
 mandatory media properties, 209
 optional media properties, 209
 storage device methods, 209
 flash memory driver example
 `at45d_attach` function, 217–218
 `at45d_delayed_attach` function, 218–219
 `at45d_get_info` function, 219–220
 `at45d_get_status` function, 220–221
 `at45d_strategy` function, 221
 `at45d_task` function, 221–223
 strategy routines, 209
 stream operations, 169–172
 `struct usb_xfer *` argument, 262–264
 sub argument, 4
 sx (shared/exclusive) locks
 avoid holding exclusive locks for long periods of time, 82
 avoid recursing on exclusive locks, 81
 example of, 75–78
 management routines for, 73–75
 `sx_destroy` function, 75
 SX_DUPOR constant, 74
 `sx_init_flags` function, 74
 `sx_init` function, 74
 SX_NOADAPTIVE constant, 74
 SX_NOPROFILE constant, 74
 SX_NOWITNESS constant, 74
 SX_QUIET constant, 74
 SX_RECURSE constant, 74
 `sx_slock_sig` function, 74
 `sx_unlock` function, 75
 `sx_xlock_sig` function, 74
 `sx_xunlock` function, 74
 synchronization primitives, 65
 synchronizing DMA buffers, 205
 `SYSCTL_ADD_*` macros, 44, 46–47
 `SYSCTL_ADD_INT` macro, 43
 `SYSCTL_ADD_LONG` macro, 42
 `SYSCTL_ADD_NODE` macro, 42, 43, 47
 `SYSCTL_ADD_OID` macro, 46
 `SYSCTL_ADD_PROC` macro, 43
 `SYSCTL_ADD_STRING` macro, 43
 `SYSCTL_CHILDREN` macro, 47
 `sysctl` contexts, 42
 `sysctl_ctx_init` function, 44
 `sysctl_debug_sleep_test` function, 90, 91
 `SYSCTL_HANDLER_ARGS` constant, 51
 `sysctl` interface
 contexts for, 44
 dynamic `sysctl`, 44–47
 overview, 40–44
 `SYSCTL_CHILDREN` macro, 47
 `sysctl_set_buffer_size` function, 50–52
 `SYSCTL_STATIC_CHILDREN` macro, 47
 `sysctl_set_buffer_size` function, 50–52
 `SYSCTL_STATIC_CHILDREN` macro, 47
 `sysinit_elem_order` enumeration, 4
 `<sys/malloc.h>` header, 20
 `<sys/module.h>` header, 4
 `SYS_RES_IOPORT` constant, 123
 `SYS_RES_IRQ` constant, 123
 `SYS_RES_MEMORY` constant, 123
 System Management BIOS (SMBIOS), 188

T

tags for DMA
 creating, 197–198
 destroying, 198–199
t argument, 30
`TASK_INIT` macro, 98
`taskqueue_drain` function, 98
`taskqueue_enqueue` function, 98
`taskqueue_run` function, 98
taskqueues
 global, 97
 management routines for, 97–98
 overview, 96–97

tasks, 96
TF_NOPREFIX flag, 105
 threads, context switches by, 84
 thread synchronization
 example of
 problem in, 61–65
 race_destroy function, 59
 race_find function, 58–59
 race_ioctl function, 59–60
 race_modevent function, 60–61
 race_new function, 58
 locks, 65
 mutex locks
 management routines for, 66–68
 race_modevent function, 71–72
 sleep mutexes, 66
 spin mutexes, 65–66
 reasons for, 54
 rw (reader/writer) locks, 78–79
 sx (shared/exclusive) locks
 avoid holding exclusive locks for long
 periods of time, 82
 avoid recursing on exclusive locks, 81
 example of, 75–78
 management routines for, 73–75
 timeout field, 260
 timo argument, 85
 transfer flags for USB drivers, 261–262
 transfers using DMA, 196
 transmit routines, 286
 transmitting packets
 em_start_locked function, 304–305
 em_txeof function, 305–307
 post transmitting, 307–308
 tsleep function, 84
 tty_alloc_mutex function, 100
 TTY device, 100
 tty_makedev function, 100
 tty_softc function, 100
 tx_buffer variable, 306
 tx_desc variable, 306
 type field, 260

U

UE_BULK endpoint type, 261
UE_CONTROL endpoint type, 261
UE_DIR_ANY constant, 260
UE_DIR_IN constant, 260
UE_DIR_OUT constant, 260
UE_INTERRUPT endpoint type, 261
UE_ISOCHRONOUS endpoint type, 261
ulpt_close function, 276
ulpt_detach function, 273
ulpt_ioctl function, 276
ulpt_open function, 273–274
ulpt_probe function, 270–273
ulpt_read_callback function, 280–281
ulpt_reset function, 274
ulpt_start_read function, 277
ulpt_start_write function, 278
ulpt_status_callback function, 281–282
ulpt_stop_read function, 278
ulpt_stop_write function, 278
ulpt_watchdog function, 277
ulpt_write_callback function, 279–280
UMASS (USB Mass Storage), 226
Universal Serial Bus (USB) drivers. *See*
 USB drivers
unload function, 89, 91–92
unlpt_open function, 275–276
USB (Universal Serial Bus) drivers
 configuration structures
 management routines for, 264–265
 mandatory fields, 260
 optional fields, 260–261
 transfer flags, 261–262
 data transfers, 262–264
 methods structure, 265
 overview, 257–259
 printer driver example
 ulpt_close function, 276
 ulpt_detach function, 273
 ulpt_ioctl function, 276
 ulpt_open function, 273–274
 ulpt_probe function, 270–273
 ulpt_read_callback function, 280–281
 ulpt_reset function, 274
 ulpt_start_read function, 277
 ulpt_start_write function, 278
 ulpt_status_callback function, 281–282
 ulpt_stop_read function, 278
 ulpt_stop_write function, 278
 ulpt_watchdog function, 277
 ulpt_write_callback function, 279–280
 unlpt_open function, 275–276
 usb_config structures, 259
 usbd_transfer_drain function, 265
 usbd_transfer_setup function, 264
 usbd_transfer_start function, 264
 usbd_transfer_stop function, 265
 usb_fifo_attach function, 265
 usb_fifo_detach function, 265
 usb_fifo_methods structure, 265
 USB frames, 261
 USB Mass Storage (UMASS), 226
 USB packets, 261
 USB_ST_SETUP constant, 264

V

variable declarations, 88
virtual null modem
 bits_per_char function, 111–112
loading, 112
 nmdm_alloc function, 105–106
 nmdm_clone function, 104
 nmdm_inwakeup function, 108
 nmdm_modem function, 108–109
 nmdm_modevent function, 103
 nmdm_outwakeup function, 106
 nmdm_param function, 109–110
 nmdm_task_tty function, 106–107
 nmdm_timeout function, 111
 overview, 99–100
vm_lowmem event handler, 93
voluntary context switching, 83–85

X

xpt_action function, 227
xpt_bus_register function, 243
xpt_done function, 227
XPT_GET_TRAN_SETTINGS constant, 246–249
XPT_GET_TRAN_SETTINGS operation, 248
XPT_PATH_INQ constant, 243–245
XPT_PATH_INQ operation, 244
XPT_RESET_BUS constant, 245–246
XPT_RESET_DEV constant, 255
xpt_run_dev_allocq function, 227
xpt_schedule function, 226, 227
XPT_SCSI_IO constant, 250–255
XPT_SET_TRAN_SETTINGS constant, 249

W

Wake-on-LAN (WOL), 293
wakeup function, 85
watchdog_list event handler, 93
WOL (Wake-on-LAN), 293
wmesg argument, 85
write operations, 29
writing
 to MMIO (memory-mapped I/O),
 167–169
 to PMIO (port-mapped I/O), 167–169