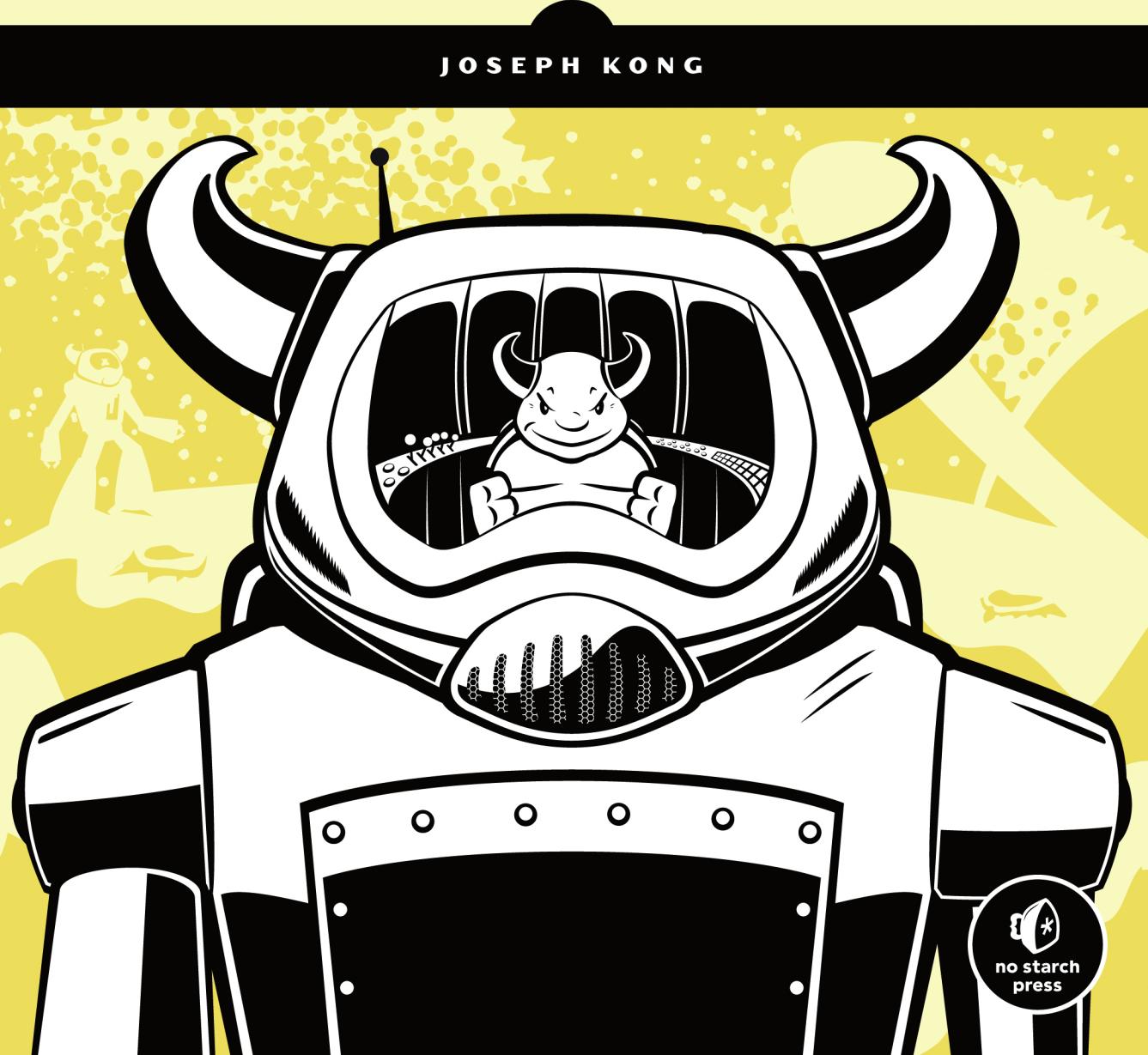


FREEBSD® DEVICE DRIVERS

A GUIDE FOR THE INTREPID

JOSEPH KONG



CONTENTS IN DETAIL

ABOUT THE AUTHOR AND THE TECHNICAL REVIEWER	xvii
FOREWORD by John Baldwin	xix
ACKNOWLEDGMENTS	xxi
INTRODUCTION	xxiii
Who Is This Book For?	xxiii
Prerequisites	xxiv
Contents at a Glance	xxiv
Welcome Aboard!	xxv
1 BUILDING AND RUNNING MODULES	1
Types of Device Drivers.....	1
Loadable Kernel Modules.....	2
Module Event Handler	2
DECLARE_MODULE Macro	3
Hello, world!	5
Compiling and Loading	6
Character Drivers	7
d_foo Functions.....	7
Character Device Switch Table	8
make_dev and destroy_dev Functions	9
Mostly Harmless.....	10
echo_write Function.....	12
echo_read Function	13
echo_modevent Function	14
DEV_MODULE Macro.....	15
Don't Panic.....	15
Block Drivers Are Gone.....	15
Conclusion	16
2 ALLOCATING MEMORY	17
Memory Management Routines.....	17
malloc_type Structures	19
MALLOC_DEFINE Macro	19
MALLOC_DECLARE Macro.....	20

Tying Everything Together	20
Contiguous Physical Memory Management Routines	22
A Straightforward Example	23
Conclusion	25

3 DEVICE COMMUNICATION AND CONTROL

ioctl	28
Defining ioctl Commands	29
Implementing ioctl	30
echo_write Function.....	34
echo_set_buffer_size Function	35
echo_ioctl Function	36
echo_modevent Function	36
Don't Panic.....	37
Invoking ioctl	37
sysctl	40
Implementing sysctls, Part 1	41
sysctl Context Management Routines	44
Creating Dynamic sysctls.....	44
SYSCTL_STATIC_CHILDREN Macro	47
SYSCTL_CHILDREN Macro	47
Implementing sysctls, Part 2	47
sysctl_set_buffer_size Function	50
Don't Panic.....	52
Conclusion	52

4 THREAD SYNCHRONIZATION

A Simple Synchronization Problem	54
A More Complex Synchronization Problem	54
race_new Function	58
race_find Function.....	58
race_destroy Function	59
race_ioctl Function	59
race_modevent Function.....	60
The Root of the Problem	61
Preventing Race Conditions	65
Mutexes	65
Spin Mutexes.....	65
Sleep Mutexes	66
Mutex Management Routines.....	66
Implementing Mutexes	68
race_modevent Function.....	71
Don't Panic.....	72
Shared/Exclusive Locks.....	73
Shared/Exclusive Lock Management Routines.....	73
Implementing Shared/Exclusive Locks	75
Reader/Writer Locks	78
Reader/Writer Lock Management Routines	78

Condition Variables.....	79
Condition Variable Management Routines.....	80
General Guidelines	81
Avoid Recursing on Exclusive Locks	81
Avoid Holding Exclusive Locks for Long Periods of Time	82
Conclusion	82

5 DELAYING EXECUTION 83

Voluntary Context Switching, or Sleeping.....	83
Implementing Sleeps and Condition Variables	85
sleep_modevent Function.....	88
load Function.....	89
sleep_thread Function	90
sysctl_debug_sleep_test Function	91
unload Function	91
Don't Panic.....	92
Kernel Event Handlers.....	92
Callouts	94
Callouts and Race Conditions	96
Taskqueues.....	96
Global Taskqueues.....	97
Taskqueue Management Routines.....	97
Conclusion	98

6 CASE STUDY: VIRTUAL NULL MODEM 99

Prerequisites	100
Code Analysis	100
nmdm_modevent Function	103
nmdm_clone Function	104
nmdm_alloc Function	105
nmdm_outwakeup Function	106
nmdm_task_tty Function.....	106
nmdm_inwakeup Function	108
nmdm_modem Function	108
nmdm_param Function.....	109
nmdm_timeout Function.....	111
bits_per_char Function	111
Don't Panic.....	112
Conclusion	112

7 NEWBUS AND RESOURCE ALLOCATION 113

Autoconfiguration and Newbus Drivers.....	113
device_foo Functions	114
Device Method Table.....	115
DRIVER_MODULE Macro	116

Tying Everything Together	117
foo_pci_probe Function.....	120
foo_pci_attach Function	120
d_foo Functions.....	121
foo_pci_detach Function	121
Don't Panic.....	122
Hardware Resource Management	122
Conclusion	124

8 INTERRUPT HANDLING 125

Registering an Interrupt Handler.....	125
Interrupt Handlers in FreeBSD	126
Implementing an Interrupt Handler.....	127
pint_identify Function.....	132
pint_probe Function.....	132
pint_attach Function.....	133
pint_detach Function.....	134
pint_open Function	134
pint_close Function	135
pint_write Function	136
pint_read Function.....	136
pint_intr Function.....	137
Don't Panic.....	138
Generating Interrupts on the Parallel Port.....	138
Conclusion	139

9 CASE STUDY: PARALLEL PORT PRINTER DRIVER 141

Code Analysis	141
lpt_identify Function.....	146
lpt_probe Function.....	146
lpt_detect Function.....	147
lpt_port_test Function	148
lpt_attach Function	148
lpt_detach Function	150
lpt_open Function	151
lpt_read Function	153
lpt_write Function	154
lpt_intr Function.....	156
lpt_timeout Function	158
lpt_push_bytes Function.....	158
lpt_close Function	159
lpt_ioctl Function	160
lpt_request_ppbus Function.....	162
lpt_release_ppbus Function.....	162
Conclusion	163

10 MANAGING AND USING RESOURCES

165

I/O Ports and I/O Memory	165
Reading from I/O Ports and I/O Memory	166
Writing to I/O Ports and I/O Memory	167
Stream Operations	169
Memory Barriers	172
Tying Everything Together	172
led_identify Function	177
led_probe Function	177
led_attach Function	178
led_detach Function	178
led_open Function	179
led_close Function	180
led_read Function	180
led_write Function	181
Conclusion	182

11 CASE STUDY: INTELLIGENT PLATFORM MANAGEMENT INTERFACE DRIVER

183

Code Analysis	183
ipmi_pci_probe Function	185
ipmi_pci_match Function	186
ipmi_pci_attach Function	187
ipmi2_pci_probe Function	189
ipmi2_pci_attach Function	189
Conclusion	191

12 DIRECT MEMORY ACCESS

193

Implementing DMA.....	194
Initiating a DMA Data Transfer	196
Dismantling DMA	196
Creating DMA Tags	197
Tearing Down DMA Tags.....	198
DMA Map Management Routines, Part 1	199
Loading (DMA) Buffers into DMA Maps	199
bus_dma_segment Structures	199
bus_dmamap_load Function	200
bus_dmamap_load_mbuf Function.....	201
bus_dmamap_load_mbuf_sg Function.....	201
bus_dmamap_load_uio Function	202
bus_dmamap_unload Function.....	202
DMA Map Management Routines, Part 2	202
A Straightforward Example	203
Synchronizing DMA Buffers	205
Conclusion	205

13 STORAGE DRIVERS

207

disk Structures	207
Descriptive Fields	208
Storage Device Methods	209
Mandatory Media Properties	209
Optional Media Properties	209
Driver Private Data	210
disk Structure Management Routines	210
Block I/O Structures	210
Block I/O Queues	212
Tying Everything Together	213
at45d_attach Function	217
at45d_delayed_attach Function	218
at45d_get_info Function	219
at45d_wait_for_device_ready Function	220
at45d_get_status Function	220
at45d_strategy Function	221
at45d_task Function	221
Block I/O Completion Routines	223
Conclusion	223

14 COMMON ACCESS METHOD

225

How CAM Works	226
A (Somewhat) Simple Example	227
mfip_attach Function	234
mfip_detach Function	235
mfip_action Function	236
mfip_poll Function	238
mfip_start Function	238
mfip_done Function	240
SIM Registration Routines	242
cam_simq_alloc Function	242
cam_sim_alloc Function	242
xpt_bus_register Function	243
Action Routines	243
XPT_PATH_INQ	243
XPT_RESET_BUS	245
XPT_GET_TRAN_SETTINGS	246
XPT_SET_TRAN_SETTINGS	249
XPT_SCSI_IO	250
XPT_RESET_DEV	255
Conclusion	255

15 USB DRIVERS

257

About USB Devices.....	257
More About USB Devices	258
USB Configuration Structures	259
Mandatory Fields	260
Optional Fields	260
USB Transfer Flags	261
USB Transfers (in FreeBSD)	262
USB Configuration Structure Management Routines	264
USB Methods Structure.....	265
Tying Everything Together	266
ulpt_probe Function	270
ulpt_attach Function.....	271
ulpt_detach Function.....	273
ulpt_open Function	273
ulpt_reset Function.....	274
unlpt_open Function	275
ulpt_close Function	276
ulpt_ioctl Function.....	276
ulpt_watchdog Function	277
ulpt_start_read Function	277
ulpt_stop_read Function	278
ulpt_start_write Function	278
ulpt_stop_write Function	278
ulpt_write_callback Function	279
ulpt_read_callback Function	280
ulpt_status_callback Function	281
Conclusion	282

16 NETWORK DRIVERS, PART 1: DATA STRUCTURES

283

Network Interface Structures	283
Network Interface Structure Management Routines	286
ether_ifattach Function	287
ether_ifdetach Function	288
Network Interface Media Structures	289
Network Interface Media Structure Management Routines	289
Hello, world!	291
mbuf Structures	293
Message Signaled Interrupts.....	294
Implementing MSI	294
MSI Management Routines	297
Conclusion	297

Packet Reception	299
em_rxeof Function	300
em_handle_rx Function	303
Packet Transmission	304
em_start_locked Function	304
em_txeof Function	305
Post Packet Transmission	307
Conclusion	308