

Table of Contents

About the Authorxix

About the Technical Reviewerxxi

Chapter 1: Introduction..... 1

STM32F103C8T6..... 2

FreeRTOS 5

libopencm3 5

No Arduino 6

No IDE 6

Development Framework..... 7

Assumptions About You..... 7

What You Need 8

ST-Link V2 Programming Unit..... 8

Breadboard 9

DuPont (Jumper) Wires..... 10

0.1 uF Bypass Capacitors 11

USB TTL Serial Adapter..... 12

Power Supply 14

Small Stuff..... 15

Summary..... 16

Chapter 2: Software Setup..... 17

Directory Conventions Used..... 17

Operating Software 17

TABLE OF CONTENTS

Book Software.....	18
libopencm3.....	18
FreeRTOS.....	19
~/stm32f103c8t6/rtos/Project.mk.....	19
ARM Cross Compiler	20
Build the Software	23
ST-Link Tool.....	24
Summary.....	25
Chapter 3: Power Up and Blink.....	27
Power	27
+3.3V Regulator.....	29
USB Power/+5V	30
+3.3V Supply	30
One Power Source Rule.....	31
Ground	32
Reset.....	32
Showtime.....	32
ST-Link V2	34
st-flash Utility.....	36
Read STM32	36
Write Image	37
Erase Flash.....	38
Summary.....	38
Bibliography	38
Chapter 4: GPIO.....	39
Building miniblink	39
Flashing miniblink.....	40
miniblink.c Source Code	41
GPIO API	44
GPIO Configuration	46

TABLE OF CONTENTS

Ducks in a Row	51
GPIO Inputs	51
Digital Output, Push/Pull.....	52
Digital Output, Open Drain	53
GPIO Characteristics	53
Input Voltage Thresholds	55
Output-Voltage Thresholds	55
Programmed Delays.....	56
The Problem with Programmed Delay.....	57
Summary.....	58
Chapter 5: FreeRTOS	59
FreeRTOS Facilities	59
Tasking	60
Message Queues	60
Semaphores and Mutexes.....	61
Timers.....	61
Event Groups	62
The blinky2 Program	62
Build and Test blinky2	66
Execution	66
FreeRTOSConfig.h	67
FreeRTOS Naming Convention	69
FreeRTOS Macros	70
Summary.....	71
Chapter 6: USART	73
USART/UART Peripheral	73
Asynchronous Data.....	74
USB Serial Adapters	74
Hookup	76
Project uart	77

TABLE OF CONTENTS

Project 81

Project uart2 85

USART API 90

 Include Files 92

 Clocks 92

 Configuration 92

 DMA 93

 Interrupts 93

 Input/Output/Status 93

Ducks-in-a-Row 93

FreeRTOS 94

 Tasks 94

 Queues 95

Summary..... 96

Chapter 7: USB Serial 97

 Blue Pill USB Issue 97

 Introduction to USB 99

 Pipes and Endpoints 99

 USB Serial Device 101

 Linux USB Serial Device 101

 MacOS USB Serial Device..... 102

 Windows USB Serial Device 103

 USB GPIO 103

 Demo Source Code 104

 cdcacm_set_config()..... 105

 cdc_control_request() 106

 cdcacm_data_rx_cb()..... 107

 USB Task..... 108

 USB Receiving 110

 USB Sending..... 110

TABLE OF CONTENTS

USB Serial Demo 111

Summary..... 113

Bibliography 114

Chapter 8: SPI Flash 115

 Introducing W25QXX 115

 Serial Peripheral Interface Bus 115

 Chip Select 117

 Wiring and Voltages..... 117

 SPI Circuit 118

 Hardware /NSS Control..... 118

 STM32 SPI Configuration 120

 SPI Clock Rate 124

 SPI Clock Modes..... 125

 Endianness and Word Length 127

 SPI I/O 128

 Read SR1 128

 Waiting for Ready 129

 Read Manufacturer ID..... 130

 Writing Flash 131

 Flash Erase 133

 Reading Flash..... 136

 Demonstration..... 137

 Running the Demo..... 139

 Manufacturer ID..... 144

 Power Down 144

 Summary 145

 Bibliography 145

Chapter 9: Code Overlays	147
The Linker Challenge	147
MEMORY Section	149
Entry	151
Sections	151
PROVIDE	154
Relocation	154
Defining Overlays	155
Overlay Code	157
Overlay Stubs	159
Overlay Manager	159
VMA and Load Addresses	160
Linker Symbols in Code	161
Overlay Manager Function	162
Overlay Stubs	164
Demonstration	165
Extracting Overlays	166
Upload Overlays to W25Q32	167
Overlay Demo Continued	171
Code Change Trap	173
Summary	173
Bibliography	174
Chapter 10: Real-Time Clock (RTC)	175
Demonstration Projects	175
RTC Using One Interrupt	175
RTC Configuration	176
Interrupt and Setup	178
Interrupt Service Routine	179
Task Notification	181
Mutexes	183

Demonstration	184
UART1 Connections	187
Running the Demo	188
rtc_alarm_isr()	190
EXTI Controller	190
Summary	192
Chapter 11: I2C	195
The I2C Bus	195
Master and Slave	196
Start and Stop	196
Data Bits	197
I2C Address	198
I2C Transactions	199
PCF8574 GPIO Extender	200
I2C Circuit	202
The PCF8574 $\overline{INT}$ Line	203
PCF8574 Configuration	203
PCF8574 GPIO Drive	205
Wave Shaping	206
Demo Circuit	206
EXTI Interrupt	207
I2C Software	209
Testing I2C Ready	210
Start I2C	211
I2C Write	213
I2C Read	213
I2C Restart	214
Demo Program	215
Demo Session	218
Summary	220

Chapter 12: OLED 223

 OLED Display 223

 Configuration 224

 Display Connections 226

 Display Features 226

 Demo Schematic 227

 AFIO 228

 Graphics 230

 The Pixmap 232

 Pixmap Writing 233

 The Meter Software 234

 Main Module 236

 Demonstration 238

 Summary 240

Chapter 13: OLED Using DMA 241

 Challenges 241

 Circuit 242

 DMA Operation 242

 DMA Execution 242

 The Demonstration 247

 Initializing DMA 249

 Launching DMA 250

 OLED SPI/DMA Management Task 251

 DMA ISR Routine 254

 Restarting DMA Transfers 255

 Executing the Demo 256

 Further Challenges 258

 Summary 259

Chapter 14: Analog-to-Digital Conversion 261

 STM32F103C8T6 Resources 261

 Demonstration 262

 Analog Inputs PA0 and PA1 263

 ADC Peripheral Configuration 263

 Demonstration Run 266

 Reading ADC 267

 Analog Voltages 270

 Summary 271

 Bibliography 272

Chapter 15: Clock Tree 273

 In the Beginning 273

 RC Oscillators 274

 Crystal Oscillators 275

 Oscillator Power 276

 Real-time Clock 276

 Watchdog Clock 276

 System Clock (SYSCLK) 277

 SYSCLK and USB 279

 AHB Bus 280

 rcc_clock_setup_in_hse_8mhz_out_72mhz() 281

 APB1 Peripherals 285

 APB2 Peripherals 285

 Timers 285

 rcc_set_mco() 286

 HSI Demo 286

 HSE Demo 288

 PLL ÷ 2 Demo 289

 Summary 290

 Bibliography 290

Chapter 16: PWM with Timer 2.....	293
PWM Signals	293
Timer 2.....	294
PWM Loop	298
Calculating Timer Prescale	298
30 Hz Cycle	299
Servo Hookup.....	300
Running the Demo	301
PWM on PB3.....	301
Other Timers	302
More PWM Channels	303
Summary.....	304
Bibliography	304
Chapter 17: PWM Input with Timer 4.....	305
The Servo Signal	305
Signal Voltage	306
Demo Project	306
GPIO Configuration	306
Timer 4 Configuration.....	306
Task1 Loop	308
ISR Routine	309
Demonstration Run	310
Session Output	312
Timer Inputs	313
Summary.....	315
Chapter 18: CAN Bus.....	317
The CAN Bus	317
Differential Signals.....	319
Dominant/Recessive.....	320

Bus Arbitration	321
Synchronization.....	322
Message Format.....	323
STM32 Limitation	324
Demonstration.....	325
Software Build	325
UART Interface.....	326
MCU Flashing.....	326
Demo Bus	327
Session Run	328
CAN Messages.....	330
Synchronicity	331
Summary.....	331
Bibliography	331
Chapter 19: CAN Bus Software	333
Initialization.....	333
can_init()	336
CAN Receive Filters	338
CAN Receive Interrupts.....	339
Application Receiving	343
Sending CAN Messages.....	345
Summary.....	346
Chapter 20: New Projects	347
Project Creation	347
Makefile.....	348
Included Makefiles	351
Header Dependencies	351
Compile Options	351
Flashing 128k	352

TABLE OF CONTENTS

FreeRTOS	353
rtos/openscm3.c	353
rtos/heap_4.c	354
Required Modules.....	354
FreeRTOSConfig.h	355
User Libraries.....	357
Rookie Mistakes.....	358
Summary.....	358
Bibliography	358
Chapter 21: Troubleshooting.....	361
Gnu GDB.....	361
GDB Server	361
Remote GDB	363
GDB Text User Interface.....	366
Peripheral GPIO Trouble	367
Alternate Function Fail.....	368
Peripheral Fail.....	369
ISR FreeRTOS Crash.....	369
Stack Overflow.....	370
Estimating Stack Size	371
When a Debugger Doesn't Help	371
Push/Pull or Open Drain.....	372
Peripheral Defects	372
Resources	372
libopenscm3.....	373
FreeRTOS Task Priorities	375
Scheduling Within libopenscm3.....	376
Summary.....	377

TABLE OF CONTENTS

Appendix A: Answers to Exercises	379
Chapter 4	379
Chapter 5	381
Chapter 6	382
Chapter 7	383
Chapter 8	384
Chapter 9	385
Chapter 10	386
Chapter 11	386
Chapter 12	387
Chapter 13	388
Chapter 14	389
Chapter 15	390
Chapter 16	390
Chapter 17	391
Chapter 19	391
Chapter 20	392
Appendix B: STM32F103C8T6 GPIO Pins	393
Index.....	401