## **Table of Contents**

reta	œ	iX
1.	Introduction	1
	Compilers, Languages, and Object-Oriented Programming	1
	Embedded System Development	2
	Debugging	2
	More Challenges	4
	Principles to Confront Those Challenges	
	Further Reading	5 7
2.	Creating a System Architecture	9
	Creating System Diagrams	10
	The Block Diagram	10
	Hierarchy of Control	13
	Layered View	14
	From Diagram to Architecture	16
	Encapsulate Modules	16
	Delegation of Tasks	17
	Driver Interface: Open, Close, Read, Write, IOCTL	18
	Adapter Pattern	19
	Getting Started with Other Interfaces	20
	Example: A Logging Interface	21
	A Sandbox to Play In	27
	Further Reading	32
3.	Getting Your Hands on the Hardware	35
	Hardware/Software Integration	35
	Ideal Project Flow	36
	Board Bring-Up	37
	Reading a Datasheet	38
	Datasheet Sections You Need When Things Go Wrong	40

iii

	Important Text for Software Developers	42
	Evaluating Components Using the Datasheet	45
	Your Processor Is a Language	48
	Reading a Schematic	50
	Having a Debugging Toolbox (and a Fire Extinguisher)	53
	Keep Your Board Safe	53
	Toolbox	54
	Digital Multimeter	55
	Oscilloscopes and Logic Analyzers	56
	Testing the Hardware (and Software)	59
	Building Tests	60
	Flash Test Example	61
	Command and Response	64
	Command Pattern	67
	Dealing with Errors	69
	Consistent Methodology	70
	Error-Handling Library	70
	Debugging Timing Errors	71
	Further Reading	72
4.	Outputs, Inputs, and Timers	75
	Toggling an Output	75
	Starting with Registers	76
	Set the Pin to Be an Output	77
	Turn On the LED	79
	Blinking the LED	80
	Troubleshooting	80
	Separating the Hardware from the Action	82
	Board-Specific Header File	82
	I/O-Handling Code	83
	Main Loop	85
	Facade Pattern	86
	The Input in I/O	87
	A Simple Interface to a Button	88
	Momentary Button Press	90
	Interrupt on a Button Press	90
	Configuring the Interrupt	91
	Debouncing Switches	91
	Runtime Uncertainty	94
	Dependency Injection	95
	Using a Timer	96
	Timer Pieces	97
	Doing the Math	99

	A Long Wait Between Timer Ticks	103
	Using the Timer	104
	Using Pulse-Width Modulation	104
	Shipping the Product	106
	Further Reading	108
5.	Managing the Flow of Activity	109
	Scheduling and Operating System Basics	109
	Tasks	109
	Communication Between Tasks	110
	Avoiding Race Conditions	110
	Priority Inversion	112
	State Machines	113
	State Machine Example: Stoplight Controller	114
	State-Centric State Machine	115
	State-Centric State Machine with Hidden Transitions	115
	Event-Centric State Machine	116
	State Pattern	117
	Table-Driven State Machine	118
	Choosing a State Machine Implementation	12:
	Interrupts	121
	An IRQ Happens	122
	Save the Context	129
	Get the ISR from the Vector Table	131
	Calling the ISR	133
	Restore the Context	136
	When to Use Interrupts	136
	How Not to Use Interrupts	137 138
	Polling	138
	System Tick Time-Based Events	140
	A Very Small Scheduler	143
	Watchdog	142
	Further Reading	144
6	Communicating with Parinharals	147
U.	Communicating with Peripherals	147
	External Memory	147
	Buttons and Key Matrices	148
	Sensors	150
	Actuators	153
	Displays	158
	So Many Ways of Communicating	163
	oo many ways or community	100

	Serial	165
	Parallel	173
	Ethernet and WiFi	175
	Putting Peripherals and Communication Together	176
	Data Handling	176
	Adding Robustness to the Communication	186
	Changing Data	189
	Changing Algorithms	191
	Further Reading	193
7.	Updating Code	197
	Onboard Bootloader	198
	Build Your Own Updater	199
	Modifying the Resident Updater	201
	Brick Loader	202
	Copy Loader to RAM	203
	Run the Loader	204
	Copy New Code to Scratch	205
	Dangerous Time: Erase and Program	205
	Reset to New Code	205
	Security	206
	Linker Scripts	207
	Summary	210
8.	Doing More with Less	. 213
	Code Space	214
	Reading a Map File (Part 1)	214
	Process of Elimination	217
	Libraries	218
	Functions and Macros	219
	Constants and Strings	220
	RAM	221
	Remove malloc	221
	Reading a Map File (Part 2)	223
	Registers and Local Variables	224
	Function Chains	226
	Pros and Cons of Globals	228
	Memory Overlays	228
	Speed	229
	Profiling	230
	Optimizing	234
	Summary	243
	Further Reading	244

9.	Math	247
	Identifying Fast and Slow Operations	248
	Taking an Average	249
	Use an Existing Algorithm	252
	Designing and Modifying Algorithms	255
	Factor Polynomials	255
	Taylor Series	256
	Dividing by a Constant	258
	Scaling the Input	259
	Lookup Tables	260
	Fake Floating-Point Numbers	267
	Rational Numbers	268
	Precision	269
	Addition (and Subtraction)	270
	Multiplication (and Division)	27
	Determining the Error	272
	Further Reading	276
10.	Reducing Power Consumption	279
	Understanding Power Consumption	280
	Turn Off the Light When You Leave the Room	282
	Turn Off Peripherals	282
	Turn Off Unused I/O devices	283
	Turn Off Processor Subsystems	283
	Slowing Down to Conserve Energy	284
	Putting the Processor to Sleep	283
	Interrupt-Based Code Flow Model	286
	A Closer Look at the Main Loop	288
	Processor Watchdog	289
	Avoid Frequent Wake-Ups	290
	Chained Processors	290
	Further Reading	290
المطمعا		20: