Contents

Introduction xxxix

Part I Introduction to Arduino 1

Chapter 1 Introduction to Arduino 3
Atmel AVR 5
The Arduino Project 7
The ATmega Series 8
  The ATmega Series 8
  The ATtiny Series 8
  Other Series 9
The Different Arduinos 9
  Arduino Uno 10
  Arduino Leonardo 10
  Arduino Ethernet 11
  Arduino Mega 2560 11
  Arduino Mini 13
  Arduino Micro 13
  Arduino Due 13
  LilyPad Arduino 14
  Arduino Pro 16
  Arduino Robot 16
  Arduino Esplora 18
  Arduino Yún 18
  Arduino Tre 19
  Arduino Zero 19
  Your Own Arduino? 20
Shields 20
  What Is a Shield? 20
  The Different Shields 21
## Contents

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Arduino Motor Shield</td>
</tr>
<tr>
<td>21</td>
<td>Arduino Wireless SD Shield</td>
</tr>
<tr>
<td>21</td>
<td>Arduino Ethernet Shield</td>
</tr>
<tr>
<td>22</td>
<td>Arduino WiFi Shield</td>
</tr>
<tr>
<td>22</td>
<td>Arduino GSM Shield</td>
</tr>
<tr>
<td>22</td>
<td>Your Own Shield</td>
</tr>
<tr>
<td>22</td>
<td>What Can You Do with an Arduino?</td>
</tr>
<tr>
<td>23</td>
<td>What You Will Need for This Book</td>
</tr>
<tr>
<td>24</td>
<td>Summary</td>
</tr>
<tr>
<td>25</td>
<td><strong>Chapter 2</strong> Programming for the Arduino</td>
</tr>
<tr>
<td>26</td>
<td>Installing Your Environment</td>
</tr>
<tr>
<td>27</td>
<td>Downloading the Software</td>
</tr>
<tr>
<td>28</td>
<td>Running the Software</td>
</tr>
<tr>
<td>29</td>
<td>Using Your Own IDE</td>
</tr>
<tr>
<td>29</td>
<td>Your First Program</td>
</tr>
<tr>
<td>33</td>
<td>Understanding Your First Sketch</td>
</tr>
<tr>
<td>36</td>
<td>Programming Basics</td>
</tr>
<tr>
<td>36</td>
<td>Variables and Data Types</td>
</tr>
<tr>
<td>38</td>
<td>Control Structures</td>
</tr>
<tr>
<td>38</td>
<td>if Statement</td>
</tr>
<tr>
<td>39</td>
<td>switch Case</td>
</tr>
<tr>
<td>40</td>
<td>while Loop</td>
</tr>
<tr>
<td>41</td>
<td>for Loop</td>
</tr>
<tr>
<td>42</td>
<td>Functions</td>
</tr>
<tr>
<td>42</td>
<td>Libraries</td>
</tr>
<tr>
<td>42</td>
<td>Summary</td>
</tr>
<tr>
<td>45</td>
<td><strong>Chapter 3</strong> Electronics Basics</td>
</tr>
<tr>
<td>46</td>
<td>Electronics 101</td>
</tr>
<tr>
<td>46</td>
<td>Voltage, Amperage, and Resistance</td>
</tr>
<tr>
<td>47</td>
<td>Voltage</td>
</tr>
<tr>
<td>48</td>
<td>Amperage</td>
</tr>
<tr>
<td>48</td>
<td>Resistance</td>
</tr>
<tr>
<td>49</td>
<td>Ohm’s Law</td>
</tr>
<tr>
<td>49</td>
<td>The Basic Components</td>
</tr>
<tr>
<td>50</td>
<td>Resistors</td>
</tr>
<tr>
<td>50</td>
<td>Different Resistor Values</td>
</tr>
<tr>
<td>50</td>
<td>Identifying Resistor Values</td>
</tr>
<tr>
<td>52</td>
<td>Using Resistors</td>
</tr>
<tr>
<td>53</td>
<td>Capacitors</td>
</tr>
<tr>
<td>54</td>
<td>Using Capacitors</td>
</tr>
<tr>
<td>54</td>
<td>Diodes</td>
</tr>
<tr>
<td>54</td>
<td>Different Types of Diodes</td>
</tr>
<tr>
<td>55</td>
<td>Using Diodes</td>
</tr>
<tr>
<td>55</td>
<td>Light-Emitting Diodes</td>
</tr>
<tr>
<td>55</td>
<td>Using LEDs</td>
</tr>
<tr>
<td>56</td>
<td>Transistors</td>
</tr>
</tbody>
</table>
## Contents

<table>
<thead>
<tr>
<th>Using Transistors</th>
<th>56</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breadboards</td>
<td>56</td>
</tr>
<tr>
<td>Inputs and Outputs</td>
<td>57</td>
</tr>
<tr>
<td>Connecting a Light-Emitting Diode</td>
<td>58</td>
</tr>
<tr>
<td>Calculation</td>
<td>58</td>
</tr>
<tr>
<td>Software</td>
<td>59</td>
</tr>
<tr>
<td>Hardware</td>
<td>60</td>
</tr>
<tr>
<td>What Now?</td>
<td>61</td>
</tr>
<tr>
<td>Summary</td>
<td>61</td>
</tr>
</tbody>
</table>

### Part II Standard Libraries

#### Chapter 4 The Arduino Language 65

<table>
<thead>
<tr>
<th>I/O Functions</th>
<th>65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital I/O</td>
<td>65</td>
</tr>
<tr>
<td>pinMode()</td>
<td>66</td>
</tr>
<tr>
<td>digitalRead()</td>
<td>66</td>
</tr>
<tr>
<td>digitalWrite()</td>
<td>67</td>
</tr>
<tr>
<td>Analog I/O</td>
<td>67</td>
</tr>
<tr>
<td>analogRead()</td>
<td>68</td>
</tr>
<tr>
<td>analogWrite()</td>
<td>68</td>
</tr>
<tr>
<td>Generating Audio Tones</td>
<td>69</td>
</tr>
<tr>
<td>tone()</td>
<td>69</td>
</tr>
<tr>
<td>noTone()</td>
<td>69</td>
</tr>
<tr>
<td>Reading Pulses</td>
<td>69</td>
</tr>
<tr>
<td>pulseIn()</td>
<td>70</td>
</tr>
<tr>
<td>Time Functions</td>
<td>70</td>
</tr>
<tr>
<td>delay()</td>
<td>70</td>
</tr>
<tr>
<td>delayMicroseconds()</td>
<td>71</td>
</tr>
<tr>
<td>millis()</td>
<td>71</td>
</tr>
<tr>
<td>micros()</td>
<td>71</td>
</tr>
<tr>
<td>Mathematical Functions</td>
<td>72</td>
</tr>
<tr>
<td>min()</td>
<td>72</td>
</tr>
<tr>
<td>max()</td>
<td>72</td>
</tr>
<tr>
<td>constrain()</td>
<td>73</td>
</tr>
<tr>
<td>abs()</td>
<td>73</td>
</tr>
<tr>
<td>map()</td>
<td>73</td>
</tr>
<tr>
<td>pow()</td>
<td>74</td>
</tr>
<tr>
<td>sqrt()</td>
<td>74</td>
</tr>
<tr>
<td>random()</td>
<td>74</td>
</tr>
<tr>
<td>Trigonometry</td>
<td>75</td>
</tr>
<tr>
<td>sin()</td>
<td>76</td>
</tr>
<tr>
<td>cos()</td>
<td>76</td>
</tr>
<tr>
<td>tan()</td>
<td>76</td>
</tr>
<tr>
<td>Constants</td>
<td>76</td>
</tr>
<tr>
<td>Interrupts</td>
<td>76</td>
</tr>
</tbody>
</table>
attachInterrupt() 77
detachInterrupt() 78
noInterrupts() 78
interrupts() 78
Summary 79

Chapter 5  Serial Communication 81
Introducing Serial Communication 82
UART Communications 84
   Baud Rate 84
   Data Bits 85
   Parity 85
   Stop Bits 86
Debugging and Output 86
Starting a Serial Connection 87
Writing Data 88
   Sending Text 88
   Sending Data 90
Reading Data 91
   Starting Communications 91
   Is Data Waiting? 91
   Reading a Byte 92
   Reading Multiple Bytes 92
   Taking a Peek 93
   Parsing Data 93
   Cleaning Up 94
Example Program 95
SoftwareSerial 98
Summary 99

Chapter 6  EEPROM 101
Introducing EEPROM 101
The Different Memories on Arduino 103
The EEPROM Library 104
   Reading and Writing Bytes 104
   Reading and Writing Bits 105
   Reading and Writing Strings 107
   Reading and Writing Other Values 108
   Example Program 110
Preparing EEPROM Storage 113
Adding Nonvolatile Memory 114
Summary 115

Chapter 7  SPI 117
Introducing SPI 118
SPI Bus 118
   Comparison to RS-232 119
   Configuration 119
   Communications 120
## Arduino SPI
- SPI Library 120
- SPI on the Arduino Due 121
- Example Program 122
  - Hardware 123
  - Sketch 124
  - Exercises 125
- Summary 126

## Chapter 8 Wire
- Introducing Wire 133
- Connecting I²C 134
- I²C Protocol 135
  - Address 136
  - Communication 137
- Communicating 138
  - Master Communications 139
    - Sending Information 140
    - Requesting Information 141
  - Slave Communications 142
    - Receiving Information 143
    - Sending Information 144
    - Example Program 145
    - Exercises 146
- Traps and Pitfalls 147
  - Voltage Difference 148
  - Bus Speed 149
  - Shields with I²C 150
- Summary 151

## Chapter 9 Ethernet
- Introduction 152
- Ethernet 153
  - Ethernet Cables 154
  - Switches and Hubs 155
  - PoE 156
- TCP/IP 157
  - MAC Address 158
  - IP Address 159
  - DNS 160
  - Port 161
- Ethernet on Arduino 162
  - Importing the Ethernet Library 163
  - Starting Ethernet 164
- Arduino as a Client 165
  - Sending and Receiving Data 166
    - Connecting to a Web Server 167
### Chapter 10 WiFi

- **Introduction** 170
- **The WiFi Protocol** 171
  - **Topology** 171
  - **Network Parameters** 172
    - **Channels** 172
    - **Encryption** 172
    - **SSID** 173
    - **RSSI** 173
- **Arduino WiFi** 173
  - **Importing the Library** 174
  - **Initialization** 174
  - **Status** 175
  - **Scanning Networks** 176
  - **Connecting and Configuring** 177
  - **Wireless Client** 178
  - **Wireless Server** 179
- **Example Application** 179
  - **Hardware** 181
  - **Sketch** 182
  - **Exercises** 189
- **Summary** 190

### Chapter 11 LiquidCrystal

- **Introduction** 192
- **LiquidCrystal Library** 194
  - **Writing Text** 195
  - **Cursor Commands** 196
  - **Text Orientation** 197
  - **Scrolling** 197
  - **Custom Text** 198
- **Example Program** 199
  - **Hardware** 200
  - **Software** 201
  - **Exercises** 205
- **Summary** 205

### Chapter 12 SD

- **Introduction** 208
- **SD Cards** 211
  - **Capacity** 212
  - **Speed** 213
Using SD Cards with Arduino 213
  Accepted SD Cards 214
  Limitations 214
The SD Library 215
  Importing the Library 215
  Connecting a Card 215
  Opening and Closing Files 216
  Reading and Writing Files 217
    Reading Files 217
    Writing Files 218
  Folder Operations 218
  Card Operations 219
  Advanced Usage 220
Example Program and Sketch 220
Summary 224

**Chapter 13** TFT 225

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>226</td>
</tr>
<tr>
<td>Technologies</td>
<td>227</td>
</tr>
<tr>
<td>TFT Library</td>
<td>228</td>
</tr>
<tr>
<td>Initialization</td>
<td>228</td>
</tr>
<tr>
<td>Screen Preparation</td>
<td>229</td>
</tr>
<tr>
<td>Text Operations</td>
<td>230</td>
</tr>
<tr>
<td>Basic Graphics</td>
<td>231</td>
</tr>
<tr>
<td>Coloring</td>
<td>232</td>
</tr>
<tr>
<td>Graphic Images</td>
<td>232</td>
</tr>
<tr>
<td>Example Application</td>
<td>233</td>
</tr>
<tr>
<td>Hardware</td>
<td>234</td>
</tr>
<tr>
<td>Sketch</td>
<td>234</td>
</tr>
<tr>
<td>Exercises</td>
<td>239</td>
</tr>
<tr>
<td>Summary</td>
<td>239</td>
</tr>
</tbody>
</table>

**Chapter 14** Servo 241

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Servo Motors</td>
<td>242</td>
</tr>
<tr>
<td>Controlling Servo Motors</td>
<td>243</td>
</tr>
<tr>
<td>Connecting a Servo Motor</td>
<td>243</td>
</tr>
<tr>
<td>Moving Servo Motors</td>
<td>244</td>
</tr>
<tr>
<td>Disconnecting</td>
<td>245</td>
</tr>
<tr>
<td>Precision and Safety</td>
<td>246</td>
</tr>
<tr>
<td>Example Application</td>
<td>246</td>
</tr>
<tr>
<td>Schematic</td>
<td>248</td>
</tr>
<tr>
<td>Sketch</td>
<td>249</td>
</tr>
<tr>
<td>Exercises</td>
<td>250</td>
</tr>
<tr>
<td>Summary</td>
<td>251</td>
</tr>
</tbody>
</table>

**Chapter 15** Stepper 253

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introducing Motors</td>
<td>254</td>
</tr>
<tr>
<td>Controlling a Stepper Motor</td>
<td>254</td>
</tr>
</tbody>
</table>
Hardware 255
Unipolar Versus Bipolar Stepper Motors 255
The Stepper Library 256
Example Project 257
Hardware 257
Sketch 258
Summary 260

**Chapter 16  Firmata** 261
Introducing Firmata 262
Firmata Library 262
  Sending Messages 263
  Receiving Messages 263
  Callbacks 264
  SysEx 266
Example Program 268
Summary 269

**Chapter 17  GSM** 271
Introducing GSM 272
Mobile Data Network 272
  GSM 273
    GPRS 274
    EDGE 274
  3 G 274
  4 G and the Future 275
  Modems 275
Arduino and GSM 276
Arduino GSM Library 276
  GSM Class 278
  SMS Class 279
  VoiceCall Class 281
  GPRS 282
  Modem 284
Example Application 285
Summary 288

Part III  Device-Specific Libraries 289

**Chapter 18  Audio** 291
Introducing Audio 292
Digital Sound Files 292
Music on the Arduino 294
Arduino Due 294
  Digital to Analog Converters 295
  Digital Audio to Analog 295
  Creating Digital Audio 296
  Storing Digital Audio 296
  Playing Digital Audio 296
## Example Program

Hardware

298

Sketch

300

Exercise

303

Summary

304

### Chapter 19 Scheduler

305

Introducing Scheduling

306

Arduino Multitasking

307

Scheduler

308

  - Cooperative Multitasking

  - Noncooperative Functions

309

Example Program

313

Hardware

314

Sketch

316

Exercises

319

Summary

319

### Chapter 20 USBHost

321

Introducing USBHost

322

USB Protocol

323

USB Devices

324

  - Keyboards

  - Mice

  - Hubs

324

Arduino Due

325

USBHost Library

327

  - Keyboards

  - Mice

327

Example Program

330

Hardware

331

  - Source Code

332

Summary

334

### Chapter 21 Esplora

335

Introducing Esplora

336

The Arduino Esplora Library

337

  - RGB LED

  - Sensors

  - Buttons

  - Buzzer

  - TinkerKit

  - LCD Module

337

Example Program and Exercises

342

Summary

344

### Chapter 22 Robot

345

Introducing Robot Library

346

Arduino Robot

348
## Contents

Robot Library
- Control Board 349
- Robotic Controls 350
- Sensor Reading 350
- Personalizing Your Robot 351
- LCD Screen 352
- Music 353
- Motor Board 354
- Example Program and Exercises 355
- Summary 356

**Chapter 23** Bridge

- Introducing Bridge Library 360
- Bridge 361
  - Process 362
  - FileIO 363
  - YunServer 364
  - YunClient 365
- Example Application 366
  - Hardware 367
  - Sketch 368
  - Exercises 369
- Summary 370

Part IV User Libraries and Shields

**Chapter 24** Importing Third-Party Libraries

- Libraries 372
  - Finding Libraries 373
  - Importing a Library 374
  - Using an External Library 375
- Example Application 376
- Exercises 377
- Summary 378

**Chapter 25** Creating Your Own Shield

- Creating a Shield 382
  - The Idea 383
  - The Required Hardware 384
  - The Required Software 385
- Your First Shield 386
  - Step 1: The Breadboard 387
  - Step 2: The Schematic 388
  - Step 3: The PCB 390
- Summary 391
## Chapter 26 Creating Your Own Library

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Libraries</td>
<td>405</td>
</tr>
<tr>
<td>Library Basics</td>
<td>406</td>
</tr>
<tr>
<td>Simple Libraries</td>
<td>406</td>
</tr>
<tr>
<td>Advanced Libraries</td>
<td>410</td>
</tr>
<tr>
<td>Adding Comments</td>
<td>413</td>
</tr>
<tr>
<td>Adding Examples</td>
<td>415</td>
</tr>
<tr>
<td>Read Me</td>
<td>415</td>
</tr>
<tr>
<td>Coding Style</td>
<td>416</td>
</tr>
<tr>
<td>Use CamelCase</td>
<td>416</td>
</tr>
<tr>
<td>Use English Words</td>
<td>416</td>
</tr>
<tr>
<td>Don't Use External Libraries</td>
<td>417</td>
</tr>
<tr>
<td>Use Standard Names</td>
<td>417</td>
</tr>
<tr>
<td>Distributing Your Library</td>
<td>417</td>
</tr>
<tr>
<td>Closed Source Libraries</td>
<td>417</td>
</tr>
<tr>
<td>Example Library</td>
<td>418</td>
</tr>
<tr>
<td>The Library</td>
<td>418</td>
</tr>
<tr>
<td>Examples</td>
<td>424</td>
</tr>
<tr>
<td>README</td>
<td>427</td>
</tr>
<tr>
<td>Finishing Touches</td>
<td>428</td>
</tr>
<tr>
<td>Summary</td>
<td>428</td>
</tr>
</tbody>
</table>

Index | 429