

ARDUINO WORKSHOP

**A Hands-On Introduction
with 65 Projects**

by John Boxall



**no starch
press**

San Francisco

BRIEF CONTENTS

Acknowledgments	xix
Chapter 1: Getting Started	1
Chapter 2: Exploring the Arduino Board and the IDE	19
Chapter 3: First Steps	33
Chapter 4: Building Blocks	55
Chapter 5: Working with Functions	95
Chapter 6: Numbers, Variables, and Arithmetic.	111
Chapter 7: Liquid Crystal Displays	147
Chapter 8: Expanding Your Arduino	161
Chapter 9: Numeric Keypads	187
Chapter 10: Accepting User Input with Touchscreens	195
Chapter 11: Meet the Arduino Family.	207
Chapter 12: Motors and Movement	225
Chapter 13: Using GPS with Your Arduino	257
Chapter 14: Wireless Data	271
Chapter 15: Infrared Remote Control	285
Chapter 16: Reading RFID Tags.	295

Chapter 17: Data Buses	307
Chapter 18: Real-time Clocks	321
Chapter 19: The Internet	337
Chapter 20: Cellular Communications	349
Index	365

CONTENTS IN DETAIL

ACKNOWLEDGMENTS

xix

1	
GETTING STARTED	1
The Possibilities Are Endless	2
Strength in Numbers.	6
Parts and Accessories	6
Required Software	7
Mac OS X	7
Windows XP and Later	11
Ubuntu Linux 9.04 and Later	15
Safety	18
Looking Ahead	18
2	
EXPLORING THE ARDUINO BOARD AND THE IDE	19
The Arduino Board.	19
Taking a Look Around the IDE	25
The Command Area	25
The Text Area	26
The Message Window Area.	26
Creating Your First Sketch in the IDE.	27
Comments	27
The Setup Function	28
Controlling the Hardware.	28
The Loop Function	28
Verifying Your Sketch	30
Uploading and Running Your Sketch	31
Modifying Your Sketch.	31
Looking Ahead	31
3	
FIRST STEPS	33
Planning Your Projects	34
About Electricity	34
Current	34
Voltage	35
Power	35
Electronic Components	35
The Resistor	35
The Light-Emitting Diode.	39
The Solderless Breadboard.	41
Project #1: Creating a Blinking LED Wave	43
The Algorithm	43
The Hardware	43

The Sketch	43
The Schematic	44
Running the Sketch	45
Using Variables	45
Project #2: Repeating with for Loops	46
Varying LED Brightness with Pulse-Width Modulation	47
Project #3: Demonstrating PWM	49
More Electric Components	49
The Transistor	50
The Rectifier Diode	50
The Relay	51
Higher-Voltage Circuits	52
Looking Ahead	53

4 BUILDING BLOCKS 55

Using Schematic Diagrams	56
Identifying Components	56
Wires in Schematics	58
Dissecting a Schematic	59
The Capacitor	60
Measuring the Capacity of a Capacitor	60
Reading Capacitor Values	61
Types of Capacitors	61
Digital Inputs	63
Project #4: Demonstrating a Digital Input	65
The Algorithm	65
The Hardware	65
The Schematic	65
The Sketch	69
Modifying Your Sketch	70
Understanding the Sketch	70
Creating Constants with #define	70
Reading Digital Input Pins	70
Making Decisions with if	71
Making More Decisions with if-then-else	71
Boolean Variables	72
Comparison Operators	72
Making Two or More Comparisons	73
Project #5: Controlling Traffic	74
The Goal	74
The Algorithm	74
The Hardware	75
The Schematic	75
The Sketch	76
Running the Sketch	79
Analog vs. Digital Signals	79
Project #6: Creating a Single-Cell Battery Tester	80
The Goal	81
The Algorithm	81
The Hardware	81

The Schematic	81
The Sketch	82
Doing Arithmetic with an Arduino	83
Float Variables	84
Comparison Operators for Calculations	84
Improving Analog Measurement Precision with a Reference Voltage	84
Using an External Reference Voltage	85
Using the Internal Reference Voltage	86
The Variable Resistor	86
Piezoelectric Buzzers	87
Piezo Schematic	88
Project #7: Trying Out a Piezo Buzzer	88
Project #8: Creating a Quick-Read Thermometer	90
The Goal	90
The Hardware	90
The Schematic	91
The Sketch	91
Hacking the Sketch	93
Looking Ahead	93

5

WORKING WITH FUNCTIONS 95

Project #9: Creating a Function to Repeat an Action	96
Project #10: Creating a Function to Set the Number of Blinks	97
Creating a Function to Return a Value	98
Project #11: Creating a Quick-Read Thermometer That Blinks the Temperature	98
The Hardware	99
The Schematic	99
The Sketch	100
Displaying Data from the Arduino in the Serial Monitor	101
The Serial Monitor	102
Project #12: Displaying the Temperature in the Serial Monitor	103
Debugging with the Serial Monitor	105
Making Decisions with while Statements	105
do-while	105
Sending Data from the Serial Monitor to the Arduino	106
Project #13: Multiplying a Number by Two	106
long Variables	107
Project #14: Using long Variables	107
Looking Ahead	109

6

NUMBERS, VARIABLES, AND ARITHMETIC 111

Generating Random Numbers	112
Using Ambient Current to Generate a Random Number	112
Project #15: Creating an Electronic Die	113
The Hardware	114
The Schematic	114
The Sketch	115
Modifying the Sketch	116

A Quick Course in Binary	116
Byte Variables	117
Increasing Digital Outputs with Shift Registers	118
Project #16: Creating an LED Binary Number Display	119
The Hardware	119
Connecting the 74HC595	119
The Sketch	121
Project #17: Making a Binary Quiz Game	122
The Algorithm	122
The Sketch	122
Arrays	124
Defining an Array	124
Referring to Values in an Array	125
Writing to and Reading from Arrays	125
Seven-Segment LED Displays	126
Controlling the LED	127
Project #18: Creating a Single-Digit Display	129
The Hardware	129
The Schematic	129
The Sketch	130
Displaying Double Digits	131
Project #19: Controlling Two Seven-Segment LED Display Modules	131
The Hardware	131
The Schematic	132
Modulo	133
Project #20: Creating a Digital Thermometer	134
The Hardware	134
The Sketch	134
LED Matrix Display Modules	135
The LED Matrix Schematic	136
Making the Connections	137
Bitwise Arithmetic	139
The Bitwise AND Operator	139
The Bitwise OR Operator	139
The Bitwise XOR Operator	140
The Bitwise NOT Operator	140
Bitshift Left and Right	140
Project #21: Creating an LED Matrix	141
Project #22: Creating Images on an LED Matrix	142
Project #23: Displaying an Image on an LED Matrix	144
Project #24: Animating an LED Matrix	145
The Sketch	145
Looking Ahead	146

7 LIQUID CRYSTAL DISPLAYS 147

Character LCD Modules	148
Using a Character LCD in a Sketch	149
Displaying Text	150
Displaying Variables or Numbers	151

Project #25: Defining Custom Characters	152
Graphic LCD Modules	153
Connecting the Graphic LCD	154
Using the LCD	155
Controlling the Display	155
Project #26: Seeing the Text Functions in Action	155
Creating More Complex Display Effects	156
Project #27: Creating a Temperature History Monitor	157
The Algorithm	158
The Hardware	158
The Sketch	158
The Result	160
Modifying the Sketch	160
Looking Ahead	160

8 EXPANDING YOUR ARDUINO **161**

Shields	162
ProtoShields	164
Project #28: Creating a Custom Shield with Eight LEDs	165
The Hardware	165
The Schematic	165
The Layout of the ProtoShield Board	166
The Design	166
Soldering the Components	167
Modifying the Custom Shield	169
Expanding Sketches with Libraries	169
Importing a Shield's Libraries	169
MicroSD Memory Cards	173
Testing Your MicroSD Card	174
Project #29: Writing Data to the Memory Card	175
Project #30: Creating a Temperature-Logging Device	177
The Hardware	177
The Sketch	177
Timing Applications with millis() and micros().	179
Project #31: Creating a Stopwatch	181
The Hardware	181
The Schematic	181
The Sketch	182
Interrupts	184
Interrupt Modes	184
Configuring Interrupts	185
Activating or Deactivating Interrupts	185
Project #32: Using Interrupts	185
The Sketch	185
Looking Ahead	186

9		
NUMERIC KEYPADS		187
Using a Numeric Keypad		187
Wiring a Keypad		188
Programming for the Keypad		189
Testing the Sketch		189
Making Decisions with switch-case		190
Project #33: Creating a Keypad-Controlled Lock		190
The Sketch		191
How It Works		192
Testing the Sketch		193
Looking Ahead		193

10		
ACCEPTING USER INPUT WITH TOUCHSCREENS		195
Touchscreens		195
Connecting the Touchscreen		196
Project #34: Addressing Areas on the Touchscreen.		197
The Hardware		197
The Sketch		197
Testing the Sketch		198
Mapping the Touchscreen		199
Project #35: Creating a Two-Zone On/Off Touch Switch.		200
The Sketch		200
How It Works		202
Testing the Sketch		202
Project #36: Creating a Three-Zone Touch Switch.		202
The Touchscreen Map		203
The Sketch		203
How It Works		205
Looking Ahead		205

11		
MEET THE ARDUINO FAMILY		207
Project #37: Creating Your Own Breadboard Arduino		208
The Hardware		208
The Schematic		211
Running a Test Sketch		214
The Many Arduino Boards		217
Arduino Uno		219
Freetronics Eleven		219
The Freeduino		220
The Boarduino		220
The Arduino Nano		221
The Arduino LilyPad		221
The Arduino Mega 2560		222
The Freetronics EtherMega		222
The Arduino Due		223
Looking Ahead		224

12		
MOTORS AND MOVEMENT		225
Making Small Motions with Servos		225
Selecting a Servo		226
Connecting a Servo		227
Putting a Servo to Work		227
Project #38: Building an Analog Thermometer		228
The Hardware		228
The Schematic		229
The Sketch		229
Using Electric Motors		231
The TIP120 Darlington Transistor		231
Project #39: Controlling the Motor		232
The Hardware		232
The Schematic		233
The Sketch		234
Project #40: Building and Controlling a Tank Robot		235
The Hardware		235
The Schematic		238
The Sketch		240
Sensing Collisions		243
Project #41: Detecting Tank Bot Collisions with a Microswitch		243
The Schematic		243
The Sketch		244
Infrared Distance Sensors		246
Wiring It Up		247
Testing the IR Distance Sensor		247
Project #42: Detecting Tank Bot Collisions with IR Distance Sensor		249
Ultrasonic Distance Sensors		251
Connecting the Ultrasonic Sensor		252
Using the Ultrasonic Sensor		252
Testing the Ultrasonic Distance Sensor		252
Project #43: Detecting Tank Bot Collisions with an Ultrasonic Distance Sensor		254
The Sketch		254
Looking Ahead		256

13		
USING GPS WITH YOUR ARDUINO		257
What Is GPS?		258
Testing the GPS Shield		259
Project #44: Creating a Simple GPS Receiver		261
The Hardware		261
The Sketch		261
Displaying the Position on the LCD		262
Project #45: Creating an Accurate GPS-based Clock		263
The Hardware		263
The Sketch		264

Project #46: Recording the Position of a Moving Object over Time	265
The Hardware	265
The Sketch	266
Displaying Locations on a Map	268
Looking Ahead	269

14

WIRELESS DATA	271
Using Low-cost Wireless Modules	271
Project #47: Creating a Wireless Remote Control	272
The Hardware for the Transmitter Circuit	273
The Transmitter Schematic	273
The Hardware for the Receiver Circuit	274
The Receiver Schematic	274
The Transmitter Sketch	275
The Receiver Sketch	276
Using XBee Wireless Data Modules for Greater Range and Faster Speed	277
Project #48: Transmitting Data with an XBee	279
The Sketch	279
Setting Up the Computer to Receive Data	279
Project #49: Building a Remote Control Thermometer	281
The Hardware	281
The Layout	281
The Sketch	282
Operation	283
Looking Ahead	284

15

INFRARED REMOTE CONTROL	285
What Is Infrared?	285
Setting Up for Infrared	286
The IR Receiver	286
The Remote Control	287
A Test Sketch	287
Testing the Setup	288
Project #50: Creating an IR Remote Control Arduino	289
The Hardware	289
The Sketch	289
Expanding the Sketch	290
Project #51: Creating an IR Remote Control Tank	291
The Hardware	291
The Sketch	291
Looking Ahead	293

16

READING RFID TAGS	295
Inside RFID Devices	296
Testing the Hardware	297
The Schematic	297
Testing the Schematic	297

Project #52: Creating a Simple RFID Control System	299
The Sketch	299
How It Works	300
Storing Data in the Arduino's Built-in EEPROM	301
Reading and Writing to the EEPROM	302
Project #53: Creating an RFID Control with "Last Action" Memory	303
The Sketch	303
How It Works	306
Looking Ahead	306

17

DATA BUSES 307

The I ² C Bus	308
Project #54: Using an External EEPROM	309
The Hardware	309
The Schematic	310
The Sketch	311
The Result.	312
Project #55: Using a Port Expander IC	313
The Hardware	313
The Schematic	313
The Sketch	314
The SPI Bus	315
Pin Connections	316
Implementing the SPI	316
Sending Data to an SPI Device	317
Project #56: Using a Digital Rheostat.	318
The Hardware	318
The Schematic	318
The Sketch	319
Looking Ahead	320

18

REAL-TIME CLOCKS 321

Connecting the RTC Module	322
Project #57: Adding and Displaying Time and Date with an RTC.	322
The Hardware	322
The Sketch	323
How It Works	325
Project #58: Creating a Simple Digital Clock	326
The Hardware	326
The Sketch	327
How It Works and Results	330
Project #59: Creating an RFID Time-Clock System.	330
The Hardware	331
The Sketch	331
How It Works	335
Looking Ahead	336

19	
THE INTERNET	337
What You'll Need	337
Project #60: Building a Remote-Monitoring Station.	339
The Hardware	339
The Sketch	339
Troubleshooting	341
How It Works	342
Project #61: Creating an Arduino Tweeter	343
The Hardware	343
The Sketch	343
Controlling Your Arduino from the Web	344
Project #62: Setting Up a Remote Control for Your Arduino	345
The Hardware	345
The Sketch	346
Controlling Your Arduino Remotely	347
Looking Ahead	348
20	
CELLULAR COMMUNICATIONS	349
The Hardware	350
Preparing the Power Shield	351
Hardware Configuration and Testing	352
Changing the Operating Frequency	354
Project #63: Building an Arduino Dialer.	356
The Hardware	356
The Schematic	356
The Sketch	357
How It Works	358
Project #64: Building an Arduino Texter	358
The Sketch	359
How It Works	359
Project #65: Setting Up an SMS Remote Control	360
The Hardware	360
The Schematic	361
The Sketch	361
How It Works	363
Looking Ahead	364
INDEX	365