

CONTENTS IN DETAIL

ACKNOWLEDGMENTS xvii

INTRODUCTION xix

Who Is This Book For?	xx
What Can You Expect to Learn?	xx
What I Expect You to Know	xxii
Materials You'll Need	xxiii
Arduino IDE and Sketch Files	xxiii
Parts and Accessories	xxiv
Project PCBs	xxiv
Moving On	xxix

1 1

MULTIPLE BUTTONS WITH ONE ANALOG INPUT 1

Voltage Dividers.	2
<i>Project #1: Three Buttons with One Analog Input</i>	3
<i>Project #2: Six Buttons with One Analog Input</i>	5
<i>Project #3: A 12-Button Keypad with One Analog Input</i>	7
Moving On	12

2 13

PORT MANIPULATION 13

Ports, Pins, and Registers.	14
<i>Project #4: Increasing Digital Output Pin Speed</i>	16
Speed Advantage	17
<i>Project #5: Displaying Binary Numbers</i>	19
<i>Project #6: Creating a Blinking LED Wave</i>	20
<i>Project #7: Controlling Seven-Segment LED Displays</i>	21
<i>Project #8: Creating an Electronic Die</i>	24
<i>Project #9: Reading Multiple Digital Inputs Simultaneously</i>	25
Binary-Coded Decimal Switches.	27
<i>Project #10: Reading BCD Switches</i>	27
Moving On	29

3 31

USING ATTINY MICROCONTROLLERS 31

The ATtiny85 Microcontroller	32
ATtiny Chips with the Arduino IDE	33
<i>Project #11: Building the "Hello, World" of Hardware</i>	35
The Arduino Uno vs. ATtiny85 Pin References	37
Adding Reset Buttons to ATtiny85 Circuits	37
Arduino Functions Available for the ATtiny85.	38
<i>Project #12: Creating a Quick-Read Thermometer</i>	39

—1
—0
—+1

Increasing the ATtiny85's Speed	41
Oscillator Speed	41
Oscillator Accuracy	42
<i>Project #13: Creating an ATtiny85 Programming Shield</i>	43
Moving On	45

4 BUILDING WATCHDOG TIMERS 47

Ensuring Constant and Reliable Operation	48
Watchdog Timer Theory	48
Watchdog Timer Circuit Configuration	49
<i>Project #14: Building a Watchdog Timer</i>	50
The 555 Circuit's Inner Workings	52
Circuit Assembly	53
Moving On	55

5 CONTROLLING LEDES WITH CHARLIEPLEXING 57

Introduction to Charlieplexing	58
<i>Project #15: Charlieplexing with Six LEDs</i>	59
Larger Charlieplexing Displays	62
<i>Project #16: Charlieplexing with 12 LEDs</i>	62
<i>Project #17: Charlieplexing with the ATtiny85</i>	65
<i>Project #18: Building a 30-LED Matrix Display</i>	67
Making Custom Character Displays	73
Moving On	74

6 ADDING PROFESSIONAL POWER CONTROL 75

Power the Arduino without a Physical Switch	76
Operating MOSFETs	76
Using the 555 Timer IC in Bistable Mode	77
<i>Project #19: Creating a Soft On/Off Switch</i>	78
<i>Project #20: Powering Off the Arduino Automatically</i>	81
Activating an Arduino from an External Device	82
Normally Open Contact Devices	82
Output Logic Devices	83
The DS3231 Real-Time Clock Library	84
<i>Project #21: Building an Event Logger</i>	86
Moving On	91

7 CONTROLLING AC MAINS POWER OUTLETS 93

Optocouplers	94
Remote-Control AC Outlets	95
Hacking the Outlet Transmitter	96
<i>Project #22: Controlling the Transmitter Board</i>	100

-1—
0—
+1—

<i>Project #23: Controlling the Mains Outlet with a Timer</i>	102
<i>Project #24: Controlling the Mains Outlet with SMS</i>	105
Moving On	109

8 CONTROLLING HIGHER-POWERED DEVICES 111

The TPIC6B595	112
<i>Project #25: Creating a TPIC6B595 Binary Number Display</i>	113
<i>Project #26: Building a PC-Controlled Relay Board</i>	116
Using Multiple TPIC6B595s	123
Piranha-Style LEDs	124
<i>Project #27: Creating a Giant Seven-Segment LED Display</i>	125
Single-Digit Display	127
Four-Digit Display	130
Moving On	132

9 BUILDING A DIGITAL MUSIC PLAYER AND SOUND BOARD 133

The YX6300 MP3 Module	134
<i>Project #28: Building a Simple MP3 Player</i>	137
<i>Project #29: Building an MP3 Player Sound Board</i>	140
Moving On	142

10 USING MULTIPLE I²C DEVICES WITH THE SAME ADDRESS 143

<i>Project #30: Using an I²C Bus Scanner</i>	144
The TCA9548A Breakout Board	146
Graphic OLED Displays	149
BMP180 Sensors	152
<i>Project #31: Creating a Temperature and Air Pressure Display</i>	154
Moving On	156

11 EMULATING USB MICE AND KEYBOARDS WITH THE LEONARDO 159

USB Keyboards	160
Emulating Keyboard Modifiers and Special Keys	162
Pressing and Releasing One or More Keys	164
<i>Project #32: Logging Data with USB Keyboard Emulation</i>	165
<i>Project #33: Building a USB Shortcut Keyboard</i>	168
USB Mice	173
<i>Project #34: Keeping Your PC Awake Automatically</i>	174
USB Mouse Buttons	175
<i>Project #35: Creating a PC Random Painter</i>	176
Moving On	177

12 TRANSFERRING DATA TO AND FROM USB FLASH DRIVES 179

Selecting and Preparing a USB Flash Drive	180
The USB Interface Module	180

—1
—0
—+1

Writing Data	183
Appending Data to a File	187
<i>Project #36: Logging Sensor Data</i>	189
Reading Numerical Data.	192
<i>Project #37: Using a USB Security Key</i>	195
<i>Project #38: Configuring a Project via USB Flash Drive</i>	197
Reading Text	201
Moving On	203

13

INTERFACING WITH PS/2 KEYBOARDS 205

The PS/2 Keyboard	206
PCF8574 LCD Modules	209
Testing the I ² C LCD and PS/2 Keyboard	211
<i>Project #39: Creating an RGB LED Tester</i>	214
<i>Project #40: Building a Text Capture Device</i>	218
Moving On	224

14

CONTROLLING THE ARDUINO WITH BLUETOOTH 225

Bluetooth Modules	226
Level Converter Modules	226
Pairing with Windows Devices	227
Pairing with macOS Devices.	227
Pairing with Android Devices	228
Sending Data via Bluetooth	228
To Windows Devices	229
To macOS Devices	230
To Android Devices	230
<i>Project #41: Capturing Data for Real-Time Monitoring</i>	231
<i>Project #42: Using Bluetooth for Digital I/O Control</i>	234
<i>Project #43: Using an Android App for Bluetooth Control</i>	236
Updating the Module Name and PIN	245
Moving On	247

15

ENERGY EFFICIENCY FOR PORTABLE PROJECTS 249

Basic Principles of Electricity	250
Measuring Power Consumption	251
USB-Sourced Power.	251
Wired Power	251
Arduino Power Consumption	252
Estimating Battery Life.	253
Software-Based Methods to Reduce Power Consumption.	256
Power Down/Wake Periodic Mode.	256
The DS3231 Real-Time Clock Library.	258
<i>Project #44: Creating a Low-Power Periodic Data Logger</i>	260
Wake on Interrupt Mode.	263
Inexpensive Sound Sensors	266

-1—
0—
+1—

<i>Project #45: Logging Interrupt Triggers</i>	266
Hardware-Based Methods to Reduce Power	269
Uploading Sketches with the ICSP Pins	270
<i>Project #46: Building a Minimalist 5 V Arduino Circuit</i>	272
Moving On	276

16
MONITORING AUTOMOTIVE ELECTRONICS WITH THE CAN BUS **277**

The CAN Bus.	277
Required CAN Bus Hardware	279
<i>Project #47: Monitoring Engine Data</i>	281
<i>Project #48: Logging OBDII Car Data</i>	285
Moving On	288

17
ARDUINO-TO-RS232 COMMUNICATION **289**

The RS232 Bus	290
Connecting to RS232	291
Testing Arduino-to-PC Connections via USB	294
<i>Project #49: Creating a PC-to-Arduino Remote Control</i>	295
<i>Project #50: Enabling Arduino-to-Arduino Communication</i>	298
Other RS232 Data Configurations	301
Moving On	302

18
ARDUINO-TO-RS485 COMMUNICATION **303**

The RS485 Bus	304
Connecting to RS485	305
<i>Project #51: Creating an Arduino-to-PC Data Link</i>	306
<i>Project #52: Creating an Arduino-to-Arduino Data Link</i>	309
<i>Project #53: Remote Control Operation</i>	312
Controlling Two or More Secondary RS485 Devices.	315
<i>Project #54: Controlling Two or More Secondary Arduino Boards</i>	316
Moving On	319

19
THE ESP32 MICROCONTROLLER PLATFORM AND IOT **321**

The ESP32	322
Configuring the Arduino IDE for the ESP32	324
Testing the ESP32.	326
The GPIO Pins	326
The Wi-Fi Connectivity.	327
Port Forwarding.	328
<i>Project #55: Remote-Controlling a Single GPIO Pin</i>	328
<i>Project #56: Remote-Controlling Four GPIO Pins</i>	334
Pulse-Width Modulation	340
<i>Project #57: Building a Hosted Web Page for a User Interface</i>	343
Moving On	349

—-1
—-0
—+1

20		
REMOTE CONTROL VIA TELEGRAM		351
Configuring Your Telegram Account		352
Configuring the Arduino IDE		355
<i>Project #58: Remote-Controlling Four LEDs</i>		355
<i>Project #59: Retrieving Remote Data</i>		362
<i>Project #60: Automating Data Transmission</i>		365
Moving On		367
21		
RETRIEVE THE CURRENT TIME FROM AN INTERNET TIME SERVER		369
The Network Time Protocol		370
<i>Project #61: Retrieving the Time and Date</i>		371
<i>Project #62: Displaying the Time and Date on an OLED</i>		374
<i>Project #63: Displaying Two Time Zones on an OLED</i>		378
<i>Project #64: Building a Giant Digital Clock</i>		380
Moving On		383
22		
CAPTURE AND LOG DATA TO GOOGLE SHEETS		385
<i>Project #65: Logging Time and Temperature Data</i>		386
Preparing the Google Sheets Document		386
The Google Apps Script		388
Preparing the Hardware		391
Tips for Future Google Sheets Projects		395
Moving On		396
23		
BUILDING A MINI WEB SERVER		397
<i>Project #66: Creating a Basic Text Web Server</i>		398
<i>Project #67: Creating an ESP32 I/O Port Monitor</i>		401
<i>Project #68: Building a Time and Weather Server</i>		407
Moving On		411
24		
THE ESP32 CAMERA BOARD		413
Selecting an ESP32 Camera		414
Setting Up the ESP32 Camera		415
<i>Project #69: Streaming Video from a Basic Camera Server</i>		418
External Wi-Fi Antenna		421
<i>Project #70: Taking Photos and Saving Them to a Memory Card</i>		423
The ESP32 Camera Pinouts		428
Moving On		429

-1—
0—
+1—

EPILOGUE 431

**APPENDIX
CREATING AND INSTALLING ARDUINO LIBRARIES 433**

Compressing Files into a ZIP File 433
 Windows 7 and Newer 434
 macOS 10 or Newer 435
 Ubuntu 20.04 LTS and Newer 436
Installing Your New Library 438

INDEX 441