Table of Contents

Preface	1
Section 1: Programming with Python and the Raspberry Pi	
Chapter 1: Setting Up your Development Environment	13
Technical requirements	14
Understanding your Python installation	14
Setting up a Python virtual environment	16
Installing Python GPIO packages with pip	19
Anatomy of a virtual environment	24
Alternative methods of executing a Python script	27
Using sudo within virtual environments	27
Executing Python scripts outside of their virtual environments	28
Running a Python script at boot	29
Configuring the GPIO interface on our Raspberry Pi	31
Configuring the PiGPIO daemon	33
Summary	34
Further reading	35
Chapter 2: Getting Started with Python and IoT	37
Technical requirements	38
Creating a breadboard prototype circuit	39
Understanding the breadboard	40
Positioning and connecting the push button	42
Positioning and connecting the LED	45
Positioning and connecting the resistor	47
Reading an electronic schematic diagram	49
Reading the push button schematic connection	50
Reading the LED and resistor schematic connection	52
Introducing ground connections and symbols	54
Exploring two ways to flash an LED in Python	56
Blinking with GPIOZero	56
Imports	57
Pin Factory configuration	58
Blinking the LED Blinking with PiGPIO	58 58
Imports	58 59
PiGPIO and pin configuration	59 59
Blinking the LED	60

	Comparing the GPIOZero and PiGPIO examples	60
	Exploring two ways to integrate a push button in Python	61
	Responding to a button press with GPIOZero	61
	Imports	62
	Button pressed handler	62
	Button configuration	63
	Preventing the main thread from terminating	64
	Responding to a button press with PiGPIO	64
	Button pin configuration	65
	Button pressed handler	65
	Creating your first IoT program	67
	Running and testing the Python server	68
	Understanding the server code	68
	Imports	69
	Variable definitions	69
	The resolve_thing_name() method	70
	The get_lastest_dweet() method The poll_dweets_forever() method	70 72
	The poli_dweets_lorever() method The process_dweet() method	72
	The main program entry point	73
	Extending your IoT program	74
	Implementing a dweeting button	74
	PiGPIO LED as a class	75
	Summary	
	Questions	76
	·	76
	Further reading	77
Cł	napter 3: Networking with RESTful APIs and Web Sockets Using Flask	78
	Technical requirements	79
	Introducing the Flask microservices framework	80
	Creating a RESTful API service with Flask-RESTful	80
	Running and testing the Python server	81
	Understanding the server code	84
	Imports	84
	Flask and Flask-RESTful API instance variables	85
	Global variables	85
	The init led() method	86
	Serving a web page	86
	The LEDControl class	87
	The get() class method	88
	The post() class method	88
	LEDController registration and starting the server	89
	Introduction to PWM	90
	Adding a RESTful API client web page	91
	Understanding the client-side code	91
	JavaScript imports	92
	The getState() function	92

The postOpdate() function	93
The updateControls() function	93
Registering event handlers with jQuery	94
The web page HTML	95
Creating a Web Socket service with Flask-SocketIO	96
Running and testing the Python server	96
Server code walkthrough	98
Imports	98
Flask and Flask-RESTful API instance variables	99
Serving a web page	99
Connecting and disconnecting handlers	99
LED handler	100
Starting the server	101
Adding a Web Socket client web page	102
Understanding the client-side code	102
Imports	103
Socket.IO connect and disconnect handlers	103
The on LED handler	104
The document ready function	104
The web page HTML	105
Comparing the RESTful API and Web Socket servers	106
Summary	107
Questions	108
Further reading	108
•	
Chapter 4: Networking with MQTT, Python, and the Mosquitto	WQTI
Broker	110
Technical requirements	111
Installing the Mosquitto MQTT broker	112
Learning MQTT by example	114
Publishing and subscribing MQTT messages	116
Exploring MQTT topics and wildcards	118
Applying Quality of Service to messages	121
Retaining messages for later delivery	124
Publishing a retained message	124
Creating durable connections	126
Saying goodbye with a Will	128
Using MQTT broker services	130
Introducing the Python Paho-MQTT client library	131
Controlling an LED with Python and MQTT	_
	132
Running the LED MQTT example	133
Understanding the code	134
Imports Clobal variables	134
Global variables The set led level(data) method	135
The set_led_level(data) method The on_connect() and on_disconnect() MQTT callback methods	135 136
The on_message() MQTT callback method	137
The on_medage() was a callback method	137

The init_mqtt() method	138
Main entry point	139
Building a web-based MQTT client	140
Understanding the code	140
Imports	140
Global variables	141
The Paho JavaScript MQTT client	141
Connecting to the broker The onConnectionLost and onMessageArrived handler methods	142 143
JQuery document ready function	143
Summary	145
Questions	146
Further reading	146
· ·	140
Section 2: Practical Electronics for Interacting with the Physical World	
Chapter 5: Connecting Your Raspberry Pi to the Physical World	148
Technical requirements	148
Understanding Raspberry Pi pin numbering	150
Exploring popular Python GPIO libraries	152
Reviewing GPIOZero – simple interfacing for beginners	153
Reviewing RPi.GPIO – a low-level GPIO for beginners	153
Reviewing Circuit Python and Blinka – interfacing for complex devices	154
Reviewing PiGPIO – a low-level GPIO library	155
Exploring remote GPIO with PiGPIO (and GPIOZero) Reviewing SPIDev and SMBus – dedicated SPI and I2C libraries	155
Why PiGPIO?	156 157
Exploring Raspberry Pi electronic interfacing options	157
Understanding digital IO	158
Understanding analog IO	158
Understanding Pulse-Width Modulation	159
Creating PWM signals	160
Understanding SPI, I2C, and 1-wire interfaces	162
Understanding the serial / UART protocol	162
Interfacing with an analog-to-digital converter	163
Building the ADS1115 ADC circuit	165
Making sure the ADS1115 is connected to your Raspberry Pi	169
Reading analog input with the ADS1115	170
Understanding the code	172
Imports	172
ADS1115 setup and configuration Global variables	173 173
Program entry point	173
Using PWM to control an LED	174
Understanding the code	176
Global variables	176

Range mapping function Generating the PWM signal	176 177
Visually exploring PWM with PiScope	177
Visualizing software and hardware-timed PWM	181
Summary	182
Questions	183
Further reading	183
Chapter 6: Electronics 101 for the Software Engineer	184
Technical requirements	185
Fitting out your workshop	186
Buying electronic modules and components	187
Purchasing lose components	187
Purchasing open source hardware modules Keeping your Raspberry Pi safe	188
Three ways electronic components fail	189
	190
Electronics interfacing principles for GPIO control	191
Ohm's Law and power Kirchhoff's circuit laws	191
Why are we using a 200 Ohm resistor for the LED circuit?	192 192
Calculating the resistor value	194
Factoring in the Raspberry Pi's current limits	195
Calculating the resistor's power dissipation	196
Exploring digital electronics	198
Digital output	198
Digital input	200
Using pull-up and pull-down resistors	203
The resistor solution	203
The code solution	205
Exploring analog electronics	207
Analog output	208
Analog input	209
Voltage dividers	209
Understanding logic-level conversion	213
Voltage dividers as logic-level converters	213
Logic-level converter ICs and modules	214
Comparing voltage dividers and logic-level converters	219
Summary	219
Questions	220
Further reading	221
Section 3: IoT Playground - Practical Examples to Interact with the Physical World	
Chapter 7: Turning Things On and Off	204
Technical requirements	224
100mmod 10quiromonto	225

Exploring a relay driver circuit	226
Determining a load's voltage and current	227
Measuring the current requirement of a DC motor	227
Measuring the current requirement of a relay and LED	230
Using an optocoupler as a switch	232
Building the optocoupler circuit	233
Controlling the optocoupler with Python	235
Using a transistor as a switch	237
Building the MOSFET circuit	239
Controlling the MOSFET with Python	242
Using a relay as a switch	245
Building the relay driver circuit	245
Controlling the Relay Driver Circuit with Python	249
Summary	251
Questions	251
Further reading	252
Chapter 8: Lights, Indicators, and Displaying Information	253
Technical requirements	253
Making color with an RGB LED and PWM	254
Creating the RGB LED circuit	255 256
Running and exploring the RGB LED code	258
Controlling a multi-color APA102 LED strip with SPI	261
Creating the APA102 circuit	262
Powering the APA102 circuit	266
Configuring and running the APA102 LED strip code	267
APA102 LED strip code walkthrough	267
Discussion of APA102 and the SPI interface	271
APA102 LED strip troubleshooting tips	272
Using an OLED display	273
Connecting the OLED display	274
Verifying whether the OLED display is connected	276
Configuring and running the OLED example	276
OLED code walkthrough	277
Making sound with buzzers and PWM Building the RTTTL circuit	281
Running the RTTTL music example	282 285
Summary	
Questions	286
· · · · · · · · · · · · · · · · · · ·	287
Further reading	287
Chapter 9: Measuring Temperature, Humidity, and Light Levels	289
Technical requirements	290
Measuring temperature and humidity	291
Creating the DHT11/DHT22 circuit	292

Running and exploring the DHT11/DHT22 code	294
Detecting light	296
Creating an LDR light-detecting circuit	298
Running the LDR example code	301
LDR code walkthrough	304
LDR configuration summary	306
Detecting moisture	307
Comparing detection options	310
Summary	312
Questions	313
Chapter 10: Movement with Servos, Motors, and Steppers	314
Technical requirements	314
Using PWM to rotate a servo	316
Connecting a servo to your Raspberry Pi	316
How a servo is controlled using PWM	319
Running and exploring the servo code	320
Different types of servos	323
Using an H-Bridge IC to control a motor	324
Building the motor driver circuit	326
Running the example H-Bridge code to control a motor	331
motor.py	331
motor_class.py	333
Introduction to stepper motor control	337
Connecting the stepper motor to the L293D circuit	339
Running and exploring the stepper motor code	340
Summary	345
Questions	345
Chapter 11: Measuring Distance and Detecting Movement	347
Technical requirements	348
Detecting movement with a PIR sensor	349
Creating the PIR sensor circuit	351
Running and exploring the PIR sensor code	352
Measuring distance with an ultrasonic sensor	354
How an ultrasonic distance sensor works	356
HC-SR04 distance measurement process	357
Building the HC-SR04 circuit	358
Running and exploring the HC-SR04 example code	361
Detecting movement and distance with Hall-effect sensors	365
Creating a Hall-effect sensor circuit	367
Running and exploring the Hall-effect sensor code	369
Summary	370
Questions	371

Chapter 12: Advanced IoT Programming Concepts - Threads, AsynclO	,
and Event Loops	372
Technical requirements	373
Building and testing our circuit	374
Building the reference circuit	376
Running the examples	380
Exploring the event-loop approach	381
Exploring a threaded approach	384
Exploring the publisher-subscriber alternative	390
Exploring an AsynclO approach	392
An asynchronous experiment	397
Summary	398
Questions	399
Further reading	399
Chapter 13: IoT Visualization and Automation Platforms	400
Technical requirements	401
Triggering an IFTTT Applet from your Raspberry Pi	402
Creating the temperature monitoring circuit	403
Creating and configuring an IFTTT Applet	403
Triggering an IFTTT Webhook	409
Triggering an IFTTT Applet in Python	412
Actioning your Raspberry Pi from an IFTTT Applet	414
Method 1 – using the dweet.io service as an intermediary	415
Method 2 – creating a Flask-RESTful service	416
Creating the LED circuit	416
Running the IFTTT and LED Python program	417
Creating the IFTTT Applet	417
Controlling the LED from an email	421
IFTTT troubleshooting	423
Visualizing data with the ThingSpeak platform	424
Configuring the ThinkSpeak platform	426
Configuring and running the ThinkSpeak Python program Other IoT and automation platforms for further exploration	428
Zapier	430
IFTTT platform	431 431
ThingsBoard IoT platform	431
Home Assistant	432
Amazon Web Services (AWS)	433
Microsoft Azure, IBM Watson, and Google Cloud	433
Summary	434
Questions	434
Chapter 14: Tying It All Together - An IoT Christmas Tree	435
Technical requirements	436

Overview of the IoT Christmas tree	438
Building the loTree circuit	439
Three IoTree service programs	440
Configuring, running, and using the Tree API service	441
Configuring the Tree API service	443
Running the Tree API service	443
Configuring, running, and using the Tree MQTT service	446
Configuring the Tree MQTT service	448
Running the Tree MQTT service program	449
Integrating the loTree with dweet.io	450
Configuring the Tree MQTT service	453
Running the dweet integration service program	454
Integrating with email and Google Assistant via IFTTT	455
Integration with email	456
Integration with Google Assistant	457
Ideas and suggestions to extend your IoTree	460
Summary	461
Questions	462
Assessments	464
Other Books You May Enjoy	474
Index	477