



Building Arduino PLCs

The essential techniques you need to
develop Arduino-based PLCs

Pradeeka Seneviratne

Apress®

Building Arduino PLCs

The essential techniques you need
to develop Arduino-based PLCs



Pradeeka Seneviratne

Apress®

Building Arduino PLCs: The essential techniques you need to develop Arduino-based PLCs

Pradeeka Seneviratne
Udumulla, Mulleriyawa, Sri Lanka

ISBN-13 (pbk): 978-1-4842-2631-5
DOI: 10.1007/978-1-4842-2632-2

ISBN-13 (electronic): 978-1-4842-2632-2

Library of Congress Control Number: 2017932449

Copyright © 2017 Pradeeka Seneviratne

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

Trademarked names, logos, and images may appear in this book. Rather than use a trademark symbol with every occurrence of a trademarked name, logo, or image we use the names, logos, and images only in an editorial fashion and to the benefit of the trademark owner, with no intention of infringement of the trademark.

The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Managing Director: Welmoed Spahr
Editorial Director: Todd Green
Acquisitions Editor: Pramila Balan
Development Editor: Anila Vincent
Technical Reviewer: Jayakarthisgeyan Prabakar
Coordinating Editor: Prachi Mehta
Copy Editor: Kezia Endsley
Compositor: SPi Global
Indexer: SPi Global
Artist: SPi Global
Cover image designed by Freepik

Distributed to the book trade worldwide by Springer Science+Business Media New York, 233 Spring Street, 6th Floor, New York, NY 10013. Phone 1-800-SPRINGER, fax (201) 348-4505, e-mail orders-ny@springer-sbm.com, or visit www.springeronline.com. Apress Media, LLC is a California LLC and the sole member (owner) is Springer Science + Business Media Finance Inc (SSBM Finance Inc). SSBM Finance Inc is a **Delaware** corporation.

For information on translations, please e-mail rights@apress.com, or visit <http://www.apress.com/rights-permissions>.

Apress titles may be purchased in bulk for academic, corporate, or promotional use. eBook versions and licenses are also available for most titles. For more information, reference our Print and eBook Bulk Sales web page at <http://www.apress.com/bulk-sales>.

Any source code or other supplementary material referenced by the author in this book is available to readers on GitHub via the book's product page, located at www.apress.com/978-1-4842-2631-5. For more detailed information, please visit <http://www.apress.com/source-code>.

Printed on acid-free paper

Contents at a Glance

About the Author xi

About the Technical Reviewer xiii

■ Chapter 1: Getting Ready for the Development Environment 1

■ Chapter 2: Arduino, Ethernet, and WiFi..... 23

■ Chapter 3: Arduino at Heart..... 57

■ Chapter 4: Your First Arduino PLC 69

■ Chapter 5: Building with an ArduiBox 85

■ Chapter 6: Writing PLC-Style Applications with plcLib 109

■ Chapter 7: Modbus 127

**■ Chapter 8: Mapping PLCs into the Cloud Using the NearBus
Cloud Connector 139**

■ Chapter 9: Building a Better PLC 165

Index..... 179

Contents

About the Author	xi
About the Technical Reviewer	xiii
■ Chapter 1: Getting Ready for the Development Environment	1
Buying an Arduino	3
Arduino UNO and Genuino UNO	3
Cable and Power Supply	5
Arduino UNO Clones and Derived Boards	6
Buying an Arduino Ethernet Shield	7
Arduino Ethernet Shield 2	7
Buying an Arduino WiFi Shield	9
Buying a Grove Base Shield	9
Buying Grove Components	10
Grove Button	10
Grove LED	11
Grove Relay	12
Grove Temperature Sensor	13
Grove Speaker	13
Grove Infrared Reflective Sensor	14
Grove Cables	15
Buying a Relay Shield	15
Arduino 4 Relays Shield	15
SeeedStudio Relay Shield	16

Buying an ArduiBox	17
Buying a Modbus Shield, Module, and Sensor	18
Multiprotocol Radio Shield for Arduino	18
RS485/Modbus Module for Arduino and Raspberry Pi.....	19
Downloading Software	20
Arduino Software	20
plcLib	21
Arduino Ethernet2 Library.....	22
WiFi Shield Firmware	22
Modbus RS485 Library	22
Summary	22
■ Chapter 2: Arduino, Ethernet, and WiFi.....	23
Arduino and Genuino	23
Digital Pins.....	24
Analog Pins.....	25
Powering the Arduino Board	25
Arduino Ethernet	27
Arduino Ethernet Shield 2.....	27
Connecting Them Together	29
Arduino WiFi	32
Arduino Software.....	33
Downloading Arduino Software	33
Using the Arduino IDE	34
Where Is the libraries Folder?.....	35
Adding the Ethernet2 Library.....	35
Cables.....	36
Basic Configurations.....	37

Writing Sketches for Arduino UNO.....	38
Bare Minimum Code	38
Hello World	40
Reading Analog Inputs.....	44
Writing Sketches for Arduino Ethernet.....	48
A Simple Web Client	48
Writing Sketches for Arduino WiFi.....	52
Summary.....	55
■ Chapter 3: Arduino at Heart.....	57
What Is PLC?	58
Arduino at Heart	59
Industruino	59
Industrial Shields.....	62
Controllino	64
Summary.....	68
■ Chapter 4: Your First Arduino PLC.....	69
Grove Base Shield Basics.....	69
Power Switch.....	71
Power Indicator	72
Reset Button	73
Grove Connectors	73
Building a Basic Programmable Logic Controller.....	76
The Requirements and Logic.....	77
Required Hardware.....	77
Connecting the Components	77

Writing Your First Arduino Sketch for PLCs	78
Uploading Your Arduino Sketch.....	79
Testing Your Sketch	79
Troubleshooting	80
Working with Audio	80
Connecting the Components	80
Testing Audio	81
Adding a Reset Button.....	82
Connecting the Components	82
Testing the Reset Button.....	83
Summary	83
■ Chapter 5: Building with an ArduiBox	85
ArduiBox	85
Soldering the Terminal Blocks	88
Soldering the Male Headers	90
Soldering the Female Headers	92
Soldering the Reset Button.....	94
Mapping Arduino Pins to the Terminal Blocks	96
Prototyping Area	98
Power Supply.....	100
Assembling the Enclosure	102
DIN Rails	105
Connecting the Temperature Sensor and Fan.....	105
Testing Your ArduiBox	107
Summary	107

■ Chapter 6: Writing PLC-Style Applications with plcLib	109
Introduction to the plcLib Library	109
Installing plcLib on Arduino	109
The Default Hardware Configuration	110
Ladder Logic.....	111
Basic Ladder Logic Symbols.....	111
Implementing Simple PLC-Style Applications	111
Single Bit Input	112
Inverted Single Bit Input	116
Inverted Single Bit Output.....	119
Time Delays	120
Boolean Operations	122
Summary	125
■ Chapter 7: Modbus	127
Multiprotocol Radio Shield	127
RS485/Modbus Module for Arduino and Raspberry Pi	129
Installing the RS485 Library for Arduino	130
Building a PLC with Modbus.....	131
Building the Hardware Setup.....	131
The Arduino Sketch.....	135
Summary	138
■ Chapter 8: Mapping PLCs into the Cloud Using the NearBus Cloud Connector	139
What Is NearBus?	139
Building Your Cloud PLC	139

Mapping a PLC Into the Cloud Using NearBus Cloud Connector	140
Signing Up with NearBus.....	140
Defining a New Device in NearBus.....	140
Downloading the NearBus Library for Arduino	143
Uploading the Sketch.....	144
Controlling the Grove LED from the NearBus Cloud.....	151
Using the IFTTT DIY Light Platform.....	154
Creating a Recipe with IFTTT.....	154
Summary	164
■ Chapter 9: Building a Better PLC	165
Using Relay Boards	165
Boards with a Single Relay.....	165
Boards with Multiple Relays.....	169
Using Relay Shields.....	170
Driving High-Power DC Loads with Relay Shields	170
Driving High-Power AC Loads with Relay Shields	173
Adding More Relay Channels.....	177
Summary	178
Index.....	179

About the Author



Pradeeka Seneviratne is a software engineer with over 10 years of experience in computer programming and systems design. He loves programming embedded systems such as Arduino and Raspberry Pi. Pradeeka started learning about electronics when he was at primary college by reading and testing various electronic projects found in newspapers, magazines, and books.

Pradeeka is currently a full-time software engineer who works with highly scalable technologies. Previously, he worked as a software engineer for several IT infrastructure and technology servicing companies, and he was also a teacher for information technology and Arduino development.

He researches how to make Arduino-based unmanned aerial vehicles and Raspberry Pi-based security cameras.

Pradeeka is also the author of the *Internet of Things with Arduino Blueprints*, Packt Publishing.

About the Technical Reviewer

Jayakarthiseyan Prabakar is an electrical and electronics engineer with more than four years of experience in real-time embedded systems development. He loves building cloud-connected physical computing systems using Arduino, MSP430, Raspberry Pi, BeagleBone Black, Intel Edison, ESP8266, and more.

Jayakarthiseyan started understanding how computing devices and operating systems work when he started repairing his personal computer in middle school. That was when he first got his hands on electronics.

From his third year in the undergraduate degree program, he started building prototypes for various startups around the world as a freelancer. Currently, Jayakarthiseyan is a full-time technical lead of the R&D division in a home automation startup and works as a consultant to many other companies involved in robotics, industrial automation, and other IoT solutions. He helps build prototypes to bring their ideas to reality.



Getting Ready for the Development Environment

A **Programmable Logic Controller (PLC)** is a *digital computer* that continuously monitors or scans the state of input devices and controls the state of output devices based on a custom program. A basic industrial PLC typically consists of an embedded computer, inputs, outputs, and a power supply with battery backup. They usually automate *industrial electromechanical* processes.

Figure 1-1 presents an industrial PLC mounted on a **DIN rail**. This unit consists of separate elements, including a *power supply*, *controller*, and unit for handling inputs and outputs. Typically for high voltage levels, the input unit consists of optically isolated inputs and output unit consists of *optically isolated* relay outputs. The passive components are enclosures, terminal block connectors, and DIN rails.

Electronic supplementary material The online version of this chapter (doi:[10.1007/978-1-4842-2632-2_1](https://doi.org/10.1007/978-1-4842-2632-2_1)) contains supplementary material, which is available to authorized users.

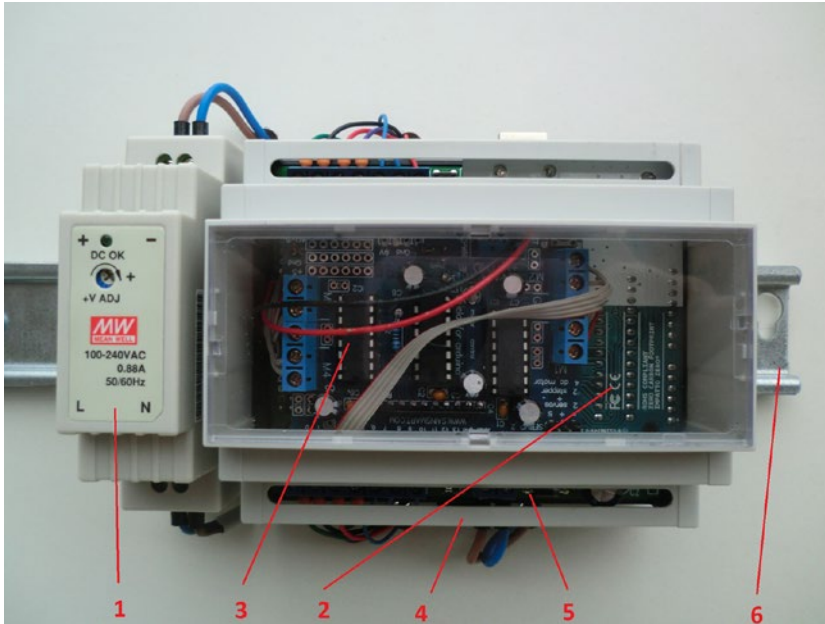


Figure 1-1. Modules of an Arduino-based PLC
Image courtesy of Hartmut Wendt at www.hwhardsoft.de

The following are the major components that can be identified in the Figure 1-1.

1. Power supply
2. Controller
3. Relay/non-relay unit for input and output
4. Enclosure
5. Terminal block connectors
6. DIN rail

Arduino Development Environment can be used to build functional PLCs that can be used with some industrial automation and process control. You'll learn how to choose appropriate components for various parts of the PLC, such as the CPU, inputs, outputs, network interfaces, power supplies, and battery backups.

This chapter provides a comprehensive shopping guide to purchasing various assembled printed circuit boards, some of the hardware components (*active and passive*), and setting up your development environment to make all the projects discussed in the chapters in the book.

We'll provide an array of manufacturers and suppliers, but the products may have same core functionalities and slightly different features. A good example is the Arduino UNO board that comes with different features depending on the manufacturer, but uses the same Arduino UNO **bootloader**.

■ **Note** This guide is only limited to the major hardware components that will be needed to build projects discussed in this book. The information presented here gives you a basic idea when it comes to purchasing those products from various vendors and manufacturers. The detailed technical guide will provide all the information about the products discussed in the respective chapters.

Buying an Arduino

Arduino comes with different flavors, including boards, modules, shields, and kits. The examples and projects discussed in this book use the Arduino UNO board, which is the basic board of the entire Arduino family. There are plenty of Arduino UNO clones and derived boards available and you may be confused about which one to buy. Following are some popular boards that can be used to start building your development environment, and buying one of them is necessary.

Arduino UNO and Genuino UNO

The Arduino online store is a very good way to purchase an Arduino UNO board. Currently, there are two brands available for Arduino. The Arduino UNO is now available for sale (`store-usa.arduino.cc`) in the United States only and the Genuino UNO is available for sale (`store.arduino.cc`) in the rest of the world.

Arduino UNO

You can purchase an Arduino UNO Rev3 board (see Figure 1-2) from the official Arduino store, which is a Dual Inline Package (DIP) type of ATmega328P microcontroller preloaded with Arduino UNO bootloader (it's about \$24.95; <http://store-usa.arduino.cc/products/a000066> and <https://www.sparkfun.com/products/11021>).



Figure 1-2. *Arduino UNO Rev3 board. Image courtesy of arduino.cc*

Also, the SMD version (Rev3) of this board is also available at the following stores if you'd like to purchase it.

- **Arduino.org:** about €20.90—<http://world.arduino.org/en/arduino/arduino-uno-smd-rev3.html>
- **SparkFun'** about \$29.95—<https://www.sparkfun.com/products/11224>

Genuino UNO

Genuino UNO (see Figure 1-3) is identical to the Arduino UNO except the brand name with the same revision that is Rev3. The board is based on the DIP type of ATmega328P microcontroller. (about €20; <https://store.arduino.cc/product/GBX00066>).

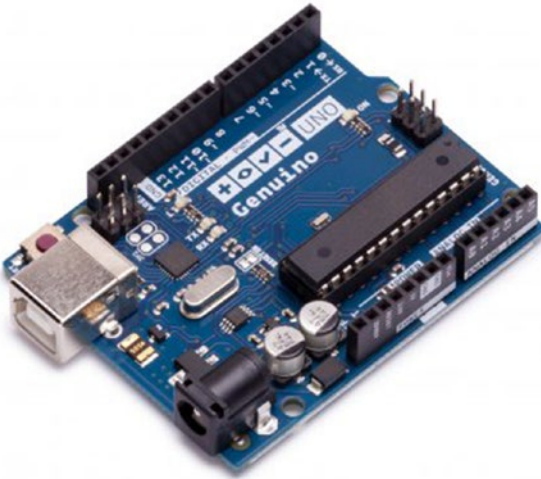


Figure 1-3. Genuino UNO Rev3 board. Image courtesy of arduino.cc

Cable and Power Supply

Don't forget to buy a USB cable and a power supply to work with the Arduino board.

USB Cable

You can use one of the following **USB cables** or a similar cable to work with Arduino.

- **Adafruit** - [USB Cable - Standard A-B - 3 ft/1m](https://www.adafruit.com/products/62) (about \$3.95; <https://www.adafruit.com/products/62>)
- **SparkFun** - [USB Cable A to B - 6 Foot](https://www.sparkfun.com/products/512) (about \$3.95; <https://www.sparkfun.com/products/512>)

Power Supply

The Arduino board can be supplied with power between **7-12V** from the DC power jack. Choosing a 9V power supply is sufficient to function the Arduino board properly. Here are some of the power packs that are ready to work with Arduino.

- **Adafruit** - [9 VDC 1000mA regulated switching power adapter](https://www.adafruit.com/product/63); UL listed (about \$6.95; <https://www.adafruit.com/product/63>)
- **SparkFun** - [Wall Adapter Power Supply - 9VDC 650mA](https://www.sparkfun.com/products/298) (about \$5.95; <https://www.sparkfun.com/products/298>)

Arduino UNO Clones and Derived Boards

There are plenty of Arduino UNO clones and derived boards (also known as *derivatives*) available from various manufacturers. The exact replicas of the Arduino boards with different branding are called clones. Arduino derivatives are different from clones, because they are derived from the Arduino hardware design but provide a different layout and a set of features (i.e., Teensy by PJRC and Flora by Adafruit), often to better serve a specific market. One of the following is a great choice for an alternative Arduino UNO board.

Seeeduino (Figure 1-4) from Seeed Development Limited is a derivative Arduino board that can be used to build Arduino projects instead of using the official Arduino board (about \$19.95; <https://www.seeedstudio.com/Seeeduino-V4.2-p-2517.html>).

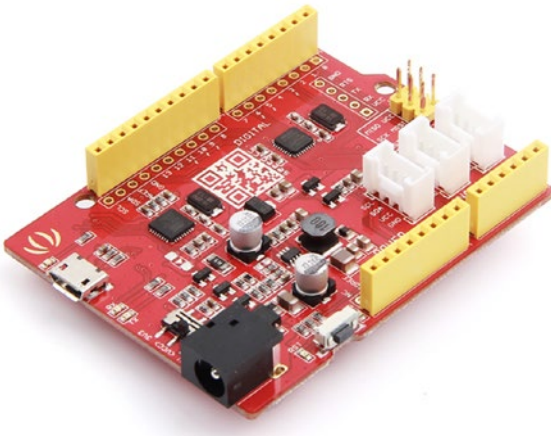


Figure 1-4. Seeeduino v4.2. Image courtesy of Seeed Development Limited

You will also need a **micro-USB cable** to program this board (about \$2.5; <https://www.seeedstudio.com/Micro-USB-Cable-48cm-p-1475.html>).

SparkFun RedBoard

SparkFun RedBoard (see Figure 1-5) is also a goof solution to use as an alternative Arduino board to build Arduino-based projects (about \$19.95; <https://www.sparkfun.com/products/12757>). This shield brings some favorite features like UNO's optiboot bootloader, the stability of the FTDI, and the R3 shield compatibility.

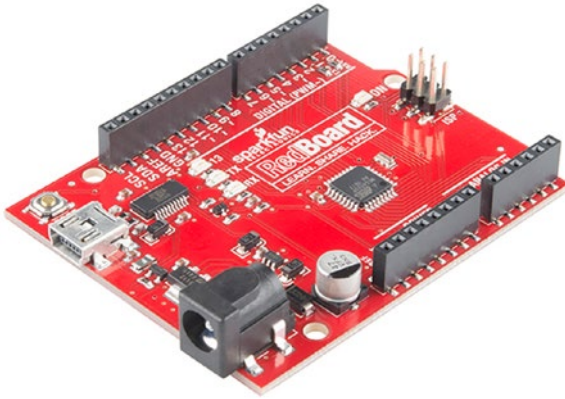


Figure 1-5. SparkFun RedBoard. Image From SparkFun Electronics; Photo taken by Juan Peña

You also need a **USB Mini-B cable** to program this board (about \$3.95; <https://www.sparkfun.com/products/11301>). You can power the board over **USB** or through the **barrel jack**.

Buying an Arduino Ethernet Shield

The main functionality of **Arduino Ethernet Shield** is to connect your Arduino board to the Internet. You only need an **Arduino Ethernet Shield** if you are planning to build a **cloud**-connected PLC that will be discussing in **Chapter 8**, “Mapping PLCs into the Cloud Using a NearBus Cloud Connector”.

Arduino Ethernet Shield 2

This is the latest version of the **Arduino Ethernet Shield** (Figure 1-6) manufactured by arduino.org at the time of this writing. It is based on the **Wiznet W5500** Ethernet chip. The shield has a standard **RJ-45** jack, on board **micro-SD card slot**, and six **TinkerKit** connectors. You learn more about Arduino Ethernet in **Chapter 2**, “**Arduino, Ethernet, and WiFi**” (about €22; <http://world.arduino.org/en/arduino-ethernet-shield-2.html>).

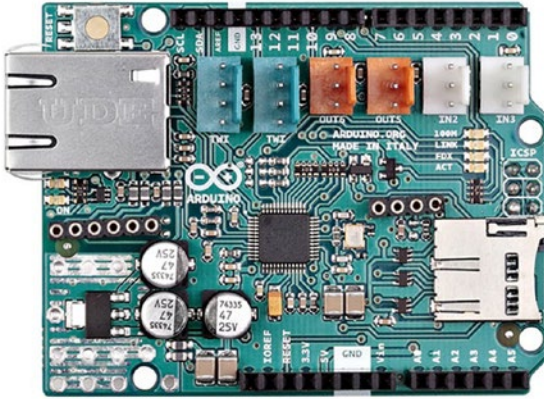


Figure 1-6. *Arduino Ethernet Shield 2. Image courtesy of arduino.org*

Alternatively, the POE (Power Over Ethernet) version of this board is also available at <http://world.arduino.org/en/arduino-ethernet-shield-2-with-poe.html> and is about €35.20.

However, you can use the previous version of Arduino Ethernet Shield (Figure 1-7) based on the **Wiznet W5100** Ethernet chip, provided that you already have one and it works well with the projects discussed in this book.

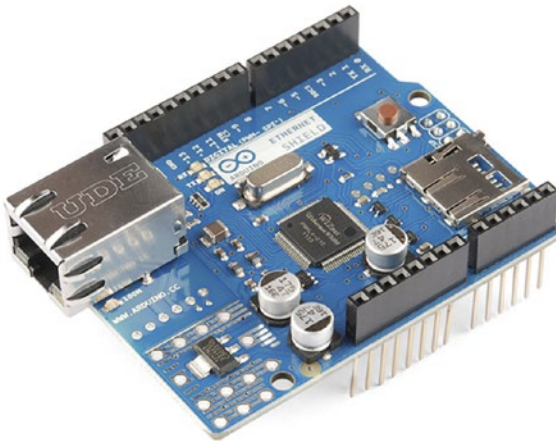


Figure 1-7. *Arduino Ethernet Shield (previous version). Image from SparkFun Electronics; photo taken by Juan Peña*