



# Programmable Logic Controllers

An Online Continuing Education Course for Engineers

**Course Number: IC-3002**

**Credit: 3 Hours / 3 PDH / 3 CPD**

# Programmable Logic Controllers

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## 1. Introduction

It would be hard to imagine today's industrial world without **Programmable Logic Controllers (PLCs)**. Before PLCs, most of the industrial processes in the world were controlled by relays and ladder logic. This worked quite well, because everyone who was concerned with industrial control systems knew all about them. They did have drawbacks. Although relays generally worked well, they would sometimes fail. But the technicians and electricians of the time understood relays and ladder logic well enough that they could get the systems to function again relatively quickly. They were also slow, but the control system designers of the time would take that into account. In more complicated systems, a condition called '**Relay Race**' could occur. One big disadvantage was that when any changes were needed by the process, the ladder logic would have to be rewired to implement the changes. This was usually a big problem. Then, the changes had to be documented. This was usually a bigger problem. Remember, this was before Auto Cad. The master drawings were done on velum. Someone had to find them, change them, copy them, and throw out the old, now wrong, copies, and make new copies to replace the outdated versions.

In 1968, someone at Hydrodynamic Division of General Motors said that there had to be a better way. So, the thought of using computers entered the picture. The initial conditions that the new computer controlled system had to follow were:

- A. The new system would adapt to change.
- B. Be able to be placed on the factory floor and keep functioning.
- C. Take up no more space than the relay ladder logic control systems.
- D. Be maintained by plant electricians.

There was resistance to changing a system that everyone knew how to operate. But Richard Morley of Bedford Associates was contracted by General Motors and invented and developed the PLC and called it a **MODULAR DIGITAL CONTROLLER**. The **MODICON** was the first PLC. At first, the PLCs were relatively simple, having only digital inputs. Since that time, many other functions have been added to the PLC, including the ability to handle analog signals and mathematical operations. A partial list of what they do consists of relay operations, timing, counting, data moves, comparisons, math functions, and other advanced operations.

We can't really talk about the PLC itself without working on the **PLC system**. The PLC system consists of 5 basic parts. They are **Input Devices, Input Interface, Processor, Output Interface, and Output Devices**. These 5 basic parts will be described in detail.

Another thing that needs to be looked at is **Digital Input/Outputs** and **Analog Input/Outputs**. Digital Inputs and Outputs have nothing to do with digital computers. They are merely inputs or outputs that have 2 states or conditions, like on and off. Since digital computers work on 2 states, 0 and 1, these 2-state input/outputs are referred to as digital input/outputs. Analog input/outputs are continuously variable, over a range. Examples are process variables, such as pressure, water depth, flow, temperature, and so forth. They are usually translated to an electrical variable such as voltage or current. Common analog input/outputs are 0 to 10 Volts DC and 4 to 20 milliamps DC.

Before we do more on PLCs, it would help to look at the physical layout of a typical PLC. Let's look at Figure 1.1. This shows the physical layout of a typical PLC as it would be purchased. This happens to be modeled after an Allen Bradley Rockwell Automation SLC 500®. The power supply is necessary to operate the processor and the input and output modules. Note that for this PLC, the processor is in a special place called slot 0. The other 7 slots can be either input or output modules. The input and output modules can be either digital or analog modules. It is possible to have more than 8 slots, but for this course, we will limit the system to 8 slots. The latest version of the SLC500® series of PLCs has a maximum of 4096 Input/output points.

|              |                  |                       |                       |                       |                       |                       |                       |                       |
|--------------|------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Power Supply | Processor Slot 0 | Input / Output Slot 1 | Input / Output Slot 2 | Input / Output Slot 3 | Input / Output Slot 4 | Input / Output Slot 5 | Input / Output Slot 6 | Input / Output Slot 7 |
|--------------|------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|

*Figure 1.1 Physical Layout of a Typical PLC System*

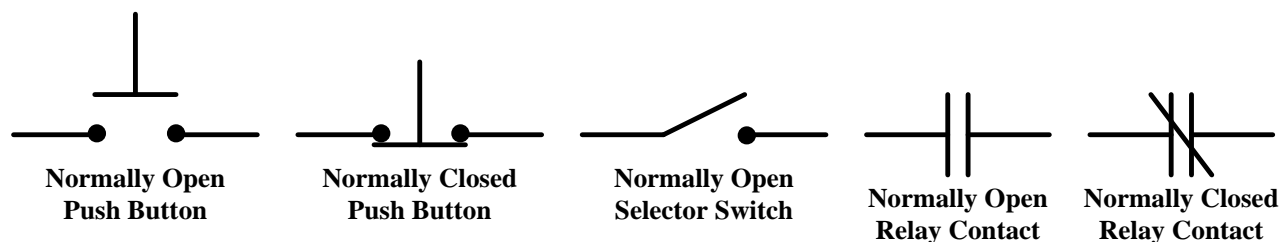
Finally, actual programming will be done on an on-line simulator. This simulator is found on line at <[thelearningpit.com](http://thelearningpit.com)>. Pick the option with the 15-day free trail. The free 15-day option has certain limits, but it will work for this course. If you find it a lot of fun to do PLC programming, and want to do more, the cost of the full-scale simulator in 2016 is \$35.

## 2. The PLC System

### 2.1 Input Devices

The first thing that any control system needs is a way to get information into the system. For most industrial control systems, digital inputs are push button switches, selector switches, limit switches, proximity switches, and contacts from relays. The important thing about these devices is that they are either off or on.

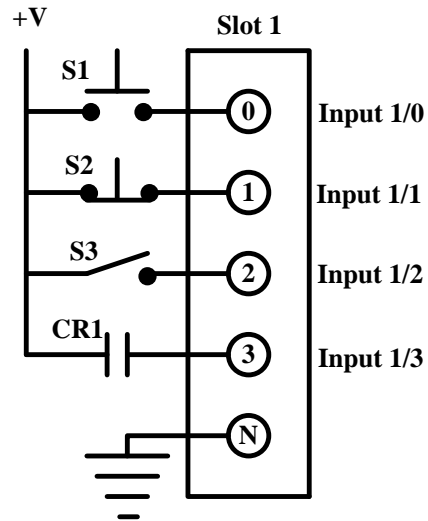
Analog inputs are the other type of input device. This course will not cover analog inputs in any great depth. We will say that analog inputs are usually 0 to 10 volts or 4-20 milliamps (ma). Even the 4-20 ma inputs are turned into 1 to 5 volts or 0.4 to 2 volts by the input module. So, we can say that an analog input is looked on as a voltage range by the processor. Figure 2.1 shows the symbols for some digital input devices.



*Figure 2.1 Symbols for Some Typical Digital Input Devices*

### 2.2 Input Modules

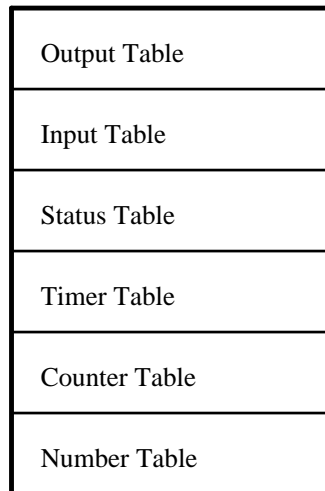
Input modules separate the input devices, voltages, and conditions from the processor. Input devices are subjected to a lot of abuse. The input module takes the signal from the input device and sends that information to the processor. It also protects the processor. There are isolation devices in the input modules that do the separation. A typical input module would have 16 inputs, corresponding to the 16 bits of the words of the special purpose computer which is the processor. There could be several input modules in a typical PLC. These modules fit in slots that are designed to accept them. The slots will accept input or output modules and are part of the PLC. Figure 2.2 shows the layout of a typical input module with input devices connected. Only 4 inputs are shown for simplicity, but 8 or 16 inputs per module is more standard. A typical PLC system will usually have more inputs than outputs.



**Figure 2.2** Layout of Typical Input Module Showing Input Devices

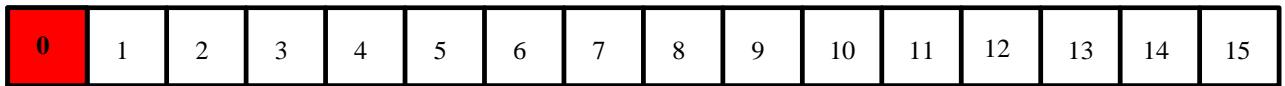
### 2.3 The Processor

The processor is a 16-bit special purpose computer. It consists of many words separated into sections. When using PLC's, it helps to have a little understanding of how the words of this special purpose computer are arranged.



**Figure 2.3** Simplified Block Diagram of the Memory Map of a Typical PLC

To help in this area, let's look at Figure 2.3. It shows a simplified memory map of a typical PLC memory. Each section is several 16-bit words. Each word has an address, and each bit of each word also has an address. As an example, let's look at the first word of the input table, as shown in figure 2.4.



**Figure 2.4** *Layout of a word in a typical PLC*

There needs to be a way to identify each bit of each word of this little computer. If this is an input word, the first bit could be labeled [I:1/0]. That address is very important. The letter I tells us that we are working with an input. The 1 tells us that this is the number 1 word in the input file and the input module located in slot number 1 in the PLC. The 0 tells us that we have the number 0 bit. That bit is shaded in red in Figure 2.4. Notice that we are counting from 0 to 15 instead of from 1 to 16. This is in deference to the way that a computer works. An important thing to notice now, is that each bit of the input word I:1/X is connected to a terminal on an input module. X is a number from 0 to 15. Therefore, the input module can have up to 16 terminals, each one of which can be connected to an input device such as a switch or relay contact. Figure 2.5 shows how this is done. Figure 2.2 is also an example of this.

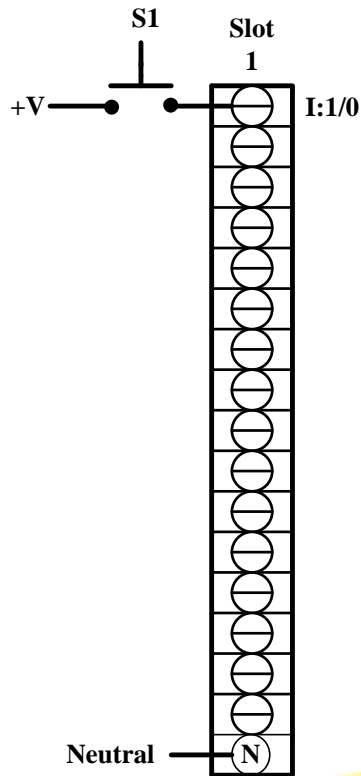


Figure 2.6.1: Output Module 1, Terminal 0

## 2.4 Output Modules

Output modules look like input modules. They are connected to output devices such as solenoids. Figure 2.6.1 shows a typical output module. All output devices all require a fuse to protect the output module. To emphasize their importance, the fuse could cause an entire system to fail. In this typical layout, slot number 2 was chosen for the fuse. In slot number 1, slot number 2 is the fuse.

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Output devices are solenoids, relays, starters, and motors. Notice that the fuse is usually fused to the output module. In this typical layout, slot number 2 was chosen for the fuse. In slot number 1, slot number 2 is the fuse. Notice that slot number 2 is the fuse. We have used slots 0 and 1 for the fuse.