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Professional paper

The importance of architecture and hardware specifications in Programmable Logic Controllers

Nexhbedin Ismaili

Department of Mechatronics, Faculty of Applied Sciences, Macedonia
e-mail: nexhbedin.ismaili95@gmail.com

Abstract

Automation is the latest and most productive trend of organizing and controlling any production process that provides high productivity, optimum execution speed, reasonable costs, high flexibility and advanced capabilities in terms of accuracy and precision of communication and execution of orders. Based on these special operating and competitive advantages, every modern industrial enterprise is automatically controlled by special microprocessor-based regulators, known as PLCs (Programmable Logic Controllers).

PLCs use programmable memory to store instructions and implement logical, sequential, timer, numerical, and arithmetic functions, thus making the core of the automation of each process. Equipped with special hardware modules and units, PLCs allow continuous reception of signals from field devices, their adaptation for reading and processing from the CPU processor, and then communication of results to output devices that will execute processed decisions, thus optimizing the regulatory capability of the entire industrial system.

All hardware components are characterized by mutual connectivity and at the same time condition the optimal operation of each other, creating the functional chain that begins with the power supply unit to all modules, to continue the further communication between input modules-CPU/memory-output modules.

The application of microprocessor-based regulators will continue to play an essential role in controlling processes by facilitating their understanding through the implementation of contemporary HMI interfaces, various simulators, and so on.

Keywords: automation, PLC, hardware modules, interaction.

Introduction

Programmable Logic Controller or how it is known on the professional vocabulary as PLC, is a special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, and arithmetic in order to control machines and processes.

The term logic is used because the programming is fundamentally related to the implementation of logic and with the switch operations. The operator (PLC user) is the one who sets a sequence of instructions, namely a program in the PLC's memory. Then, the controller monitors the incoming and outgoing values from the respective units by complying with the program, in order to deploy the control rules for which it is programmed.

Architecture and functionality of hardware components

There are six standardized hardware components that make the PLC functional and capable of controlling various systems: power supply unit, central processing unit (CPU), memory unit, input/output modules, programming device and communication interface. These components are designed in such a way that create the appropriate conditions for receiving signals from input field devices, processing and memorizing them as well as delivering results and executing orders towards output field devices. Extensive industrial application and technology advancement have enabled the production of various PLC regulators equipped with advanced hardware components that meet complex requirements and provide optimal control of manufacturing processes.

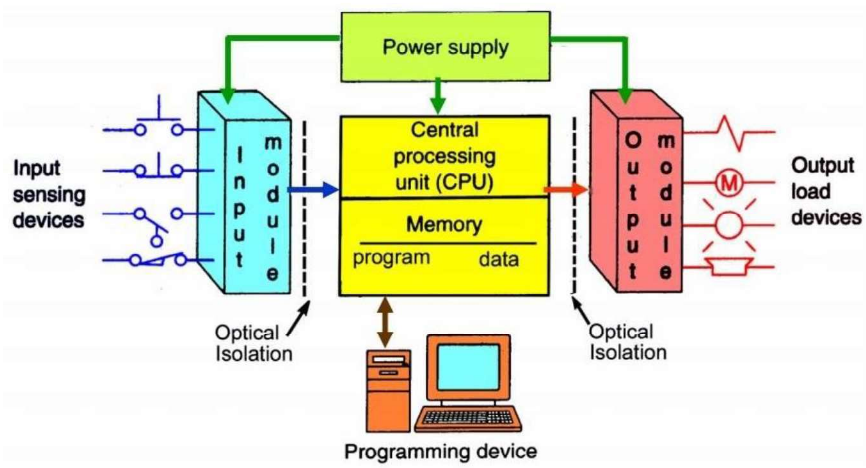


Figure 1. PLC hardware components

The power supply unit

The power supply unit provides the required input energy (5 VDC) for the PLC modules. This unit converts the current of 115 VAC or 230 VAC to the usable voltage adapted for the CPU, memory and I/O modules. The power supply units are designed to cope with current power losses without affecting the operation of the PLC's. The ways of converting high voltage to low voltage and vice versa (energy flow inside the PLC) will be treated more deeply in the following material. For large PLC systems, this power supply does not normally supply power to the field devices. With larger systems, power to field devices is provided by external alternating current (AC) or direct current (DC) supplies. For some small micro PLC systems, the power supply may be used to power field devices.

The central processing unit (CPU)

The processor unit or central processing unit (CPU) is the unit containing the microprocessor. This unit interprets the input signals and carries out the control actions according to the program stored in its memory, communicating the decisions as action signals to the outputs. The CPU executes the operating system, manages memory, monitors inputs, evaluates the user logic (ladder program), and turns on the appropriate outputs. Each PLC processor has three essential modes of operation: RUN, PROG and REM.

- **RUN** mode: the processor scans/executes the ladder program, monitors input devices, energizes output devices, and acts on enabled I/O forces. The operator can't perform online program editing while the CPU is in this mode.
- **PROG** mode: this position places the processor in the Program mode. The processor does not scan/execute the ladder program, and the controller outputs are de-energized. In this mode, the operator can perform online program editing, but cannot use a programmer/operator interface device to change the processor mode.
- **REM** mode: This position places the processor in the Remote mode: either the REMote Run, REMote Program, or REMote Test mode. This mode allows the operator to change the processor mode from a programmer/operator interface device and to perform online program editing.

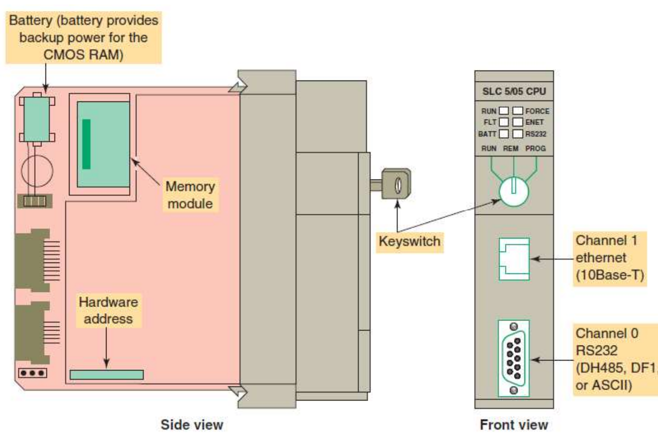


Figure 2. The processor module of a PLC (Allen Bradley SLC 5/05)

The memory unit

Memory is the element that stores information, programs and data in a PLC. The user memory of a PLC includes space for the user program as well as addressable memory locations for storage of data. The complexity of the program determines the amount of memory required. Memory elements store individual pieces of information called bits. The program is stored in the memory as 1s and 0s, which are typically assembled in the form of 16-bit words.
Sections of memory used to store the status of inputs and outputs are called input status files or tables and output status files or tables (figure 3). Each bit is either a 1 or 0, depending on whether the input is open or closed. A closed contact would have a binary 1 stored in its respective

location in the input table, whereas an open contact would have a 0 stored. A lamp that is ON would have a 1 stored in its respective location in the output table, whereas a lamp that is OFF would have a 0 stored. Input and output image tables are constantly being revised by the CPU. Each time a memory location is examined, the table changes if the contact or coil has changed state.

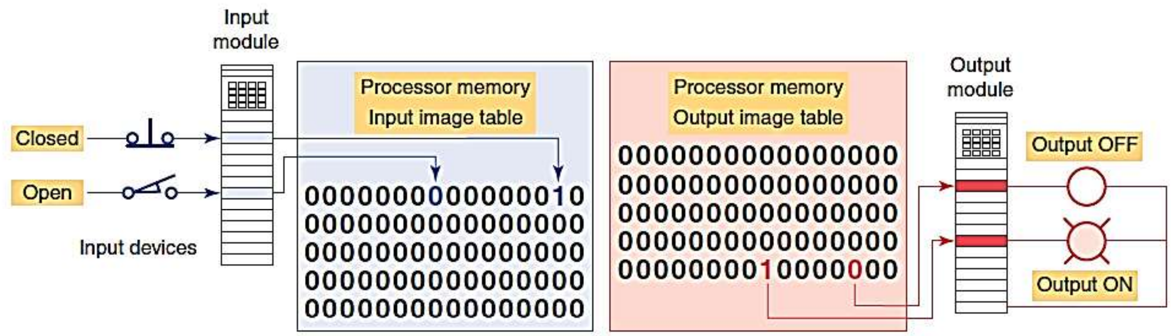


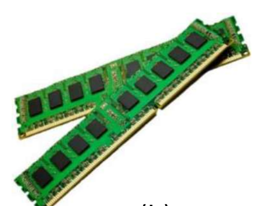
Figure 3. Input and output memory tables

Memory can be separated into two categories: volatile and nonvolatile. **Volatile memory** loses its programmed contents if all operating power is lost or removed, whether it is normal power or some form of backup power. **Nonvolatile memory** retains its programmed contents, even during a complete loss of operating power, without requiring a backup source.

- **Read-only memory (ROM)** is designed to permanently store a fixed program that is not alterable under ordinary circumstances. It gets its name from the fact that its contents can be examined, or *read*, but not altered once information has been stored. Executive programs are often stored in ROM.

(a

- **Random-access memory (RAM),** often referred to as *read/write memory (R/W)*, is designed so that information can be written into or read from the memory storage area. Random-access memory does not retain its contents if power is lost; therefore, it is a volatile type of memory. Random-access memory normally uses a battery backup to sustain its contents in the event of a power outage.



(b)

- **Erasable programmable read-only memory (EPROM)** is a specially designed memory that can be reprogrammed after being entirely erased by an ultraviolet (UV) light source. Complete erasure of the contents of the chip requires that the window of the chip be exposed to a UV light source for approximately twenty minutes. EPROM, with its permanent storage capability, combined with RAM, which is easily altered, makes a suitable memory system for many applications.

(c)

- **Electrically erasable programmable read-only memory (EEPROM)**: like ROMs and EPROMs, it is a nonvolatile memory, yet it offers the same programming flexibility as RAM does. Several of today's small and medium-sized controllers use EEPROM as the only memory within the system. It provides permanent storage for the program and can be easily changed with the use of a programming device or a manual programming unit. These two features help to eliminate downtime and delays associated with programming changes.

(d)

Figure 4 (a, b, c, d). Memory types

The discrete I/O modules

This type of interface connects field input devices of the ON/OFF nature such as selector switches, pushbuttons, and limit switches. Likewise, output control is limited to devices such as lights, relays, solenoids, and motor starters that require simple ON/OFF switching. The classification of discrete I/O covers bit-oriented inputs and outputs. In this type of input or output, each bit represents a complete information element in itself and provides the status of some external contact or advises of the presence or absence of power in a process circuit. Each discrete I/O module is powered by some field supplied voltage source. Since these voltages can be of different magnitude or type, I/O modules are available at various AC and DC voltage ratings, as listed in Table 1.

Table 1. Common Ratings for Discrete I/O Interface Modules

Input Interfaces	**Output Interfaces**
12 V AC/DC /24 V AC/DC	12-48 V **AC**
48 V AC/DC	120 V **AC**
120 V AC/DC	230 V **AC**
230 V AC/DC	120 V **DC**
5 V DC (TTL level)	230 V **DC**
	5 V **DC** (TTL level)
	24 V **DC**

Below, we are going to explain the processes that occur during signal receiving from input field devices and their orientation to the PLC's processor. The input circuit (figure 5) is composed of two basic sections: the power section and the logic section. An optical isolator is used to provide electrical isolation between the field wiring and the PLC backplane internal circuitry. The input LED turns on or off, indicating the status of the input device. Logic circuits process the digital signal to the processor. Internal PLC control circuitry typically operates at 5 VDC or less volts.

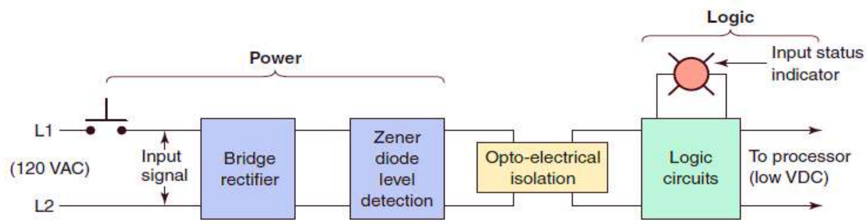


Figure 5. Discrete AC input module block diagram

A simplified diagram for a single input of a discrete AC input module is shown in figure 6. The operation of the circuit can be summarized as follows:

- The input noise filter consisting of the capacitor and resistors R1 and R2 removes false signals that are due to contact bounce or electrical interference.
- When the pushbutton is closed, 120 VAC is applied to the bridge rectifier input.
- This results in a low-level DC output voltage that is applied across the LED of the optical isolator.
- The Zener diode (Z D) voltage rating sets the minimum threshold level of voltage that can be detected.
- When light from the LED strikes the phototransistor, it switches into conduction and the status of the pushbutton is communicated in logic to the processor.
- The optical isolator not only separates the higher AC input voltage from the logic circuits but also prevents damage to the processor due to line voltage transients.
- For fault diagnosis, an input state LED indicator is on when the input pushbutton is closed. This indicator may be wired on either side of the optical isolator.
- An AC/DC type of input module is used for both AC and DC inputs as the input polarity does not matter.

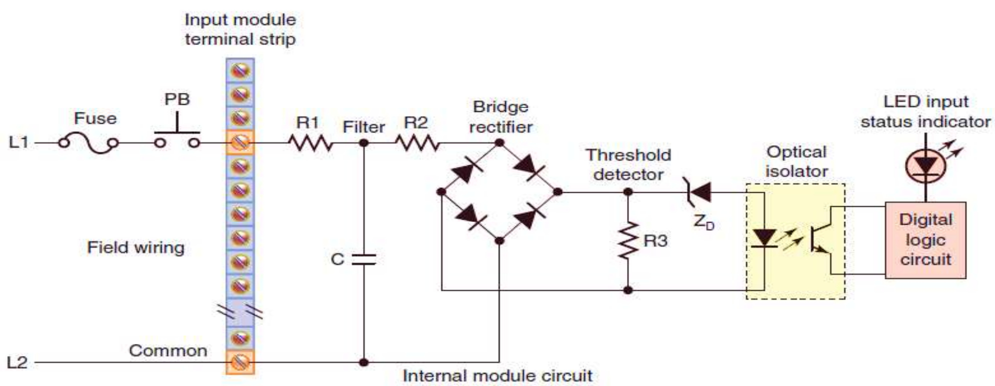


Figure 6. Simplified diagram for a single input of a discrete AC input module.

Discrete input modules perform four tasks in the PLC control system. They:

- Sense when a signal is received from a field device.
- Convert the input signal to the correct voltage level for the particular PLC.
- Isolate the PLC from fluctuations in the input signal's voltage or current.
- Send a signal to the processor indicating which device originated the signal.

Figure 7 shows the block diagram for one output of a typical discrete output module. The output interface can be thought of as an electronic switch that turns the output load device on and off. An output LED indicates the status of the output signal.

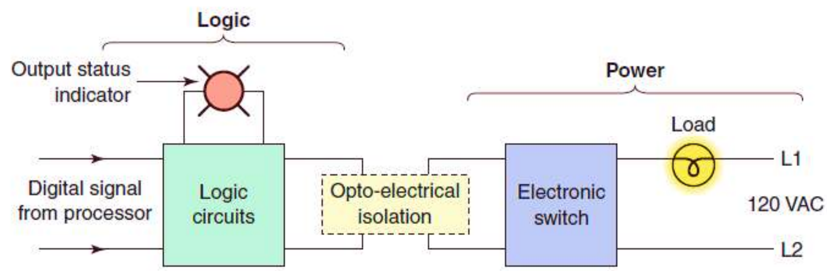


Figure 7. Discrete AC output module block diagram.

Figure 8 shows a simplified diagram for a single output of a discrete AC output module.

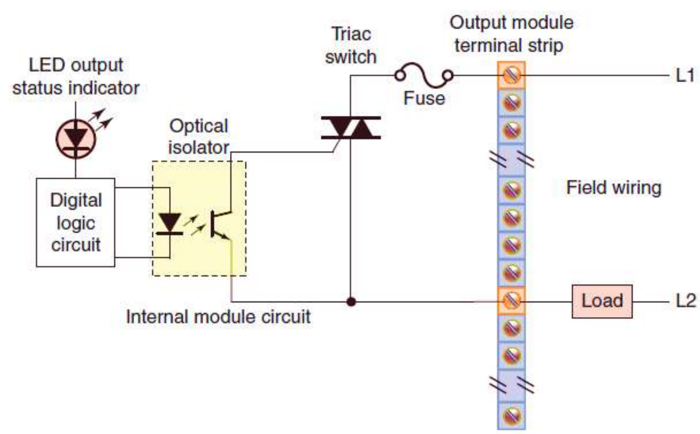


Figure 8. Diagram for a single output of a discrete AC output module.

The operation of the circuit can be summarized as follows:

- As part of its normal operation, the digital logic circuits of the processor, sets the output status according to the program.
- When the processor calls for an output load to be energized, a voltage is applied across the LED of the opto-isolator.
- The LED then emits light, which switches the phototransistor into conduction.
- This in turn triggers the triac AC semiconductor switch into conduction allowing current to fl ow to the output load.
- Since the triac conducts in either direction, the output to the load is alternating current.
- The triac, rather than having ON and OFF status, actually has LOW and HIGH resistance levels, respectively. In its OFF state (HIGH resistance), a small leakage current of a few mill amperes still flows through the triac.
- As with input circuits, the output interface is usually provided with LEDs that indicate the status of each output.

- Fuses are normally required for the output module, and they are provided on a per circuit basis, thus allowing for each circuit to be protected and operated separately.
- The triac cannot be used to switch a DC load.

Human Machine Interfaces (HMIs)

A human-machine interface (HMI) is the user interface that connects an operator to the PLC controller for a certain industrial system. HMI includes electronic components for signaling and controlling automation systems, and also translate data from industrial control systems into human-readable visual representations of the systems. Through the HMI, an operator can see schematics of the systems and turn switches and pumps on or off, for example, or raise or lower temperatures. HMIs are usually deployed on Windows-based machines, communicating with programmable logic controllers (PLC) and other industrial controllers.
Through configuration software it is possible to perform the following functions:

- Replacement of push buttons, warning lights and other elements with corresponding graphic icons. The machine operator only needs one touch on the screen to activate multiple units
- Presentation of different operations in graphic form and real time observation
- Appearance of variables by numeric or percentage change
- Allowing the change of instruction values in the program, such as timers and counters
- Showing detailed reminders for performing various tasks, etc.

Figure 9. Human Machine Interfaces (HMIs).

Conclusions

From this research conducted in the field of automation and process control, we can conclude that programmable logic controllers are a necessity of the time in which we live and act. By understanding the PLC hardware concepts, we will be able to quickly adapt and understand the logic of functionality and opportunities that these controllers offer. Although not a brand new discovery, PLCs continue to be used massively by adapting to different application areas. This has resulted in the production giants of these regulators and their respective software to expand their research and to develop more new PLC models, in order to adapt towards complex automation processes. Thus, specific modules have been developed for specific tasks depending on their application. In addition, over time, the understanding and functionality of these regulators is facilitated, thanks to the implementation of visual and operational technologies such as: contemporary HMI interfaces, various language programming simulators, voice command systems, and so on.

Extremely practical use, high reliability and optimum flexibility offered by these controllers are the key determinants that prove that PLCs will continue to be present in controlling various processes for a long period of time.

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