2

PLC Hardware Components

Courtesy of Nercon

Chapter Objectives

After completing this chapter, you will be able to:

- List and describe the function of the hardware components used in PLC systems
- Describe the basic circuitry and applications for discrete and analog I/O modules, and interpret typical I/O and CPU specifications
- Explain I/O addressing
- Describe the general classes and types of PLC memory devices
- List and describe the different types of PLC peripheral support devices available

This chapter exposes you to the details of PLC hardware and modules that make up a PLC control system. The chapter's illustrations show the various parts of a PLC as well as general connection paths. In this chapter we discuss the CPU and memory hardware components, including the various types of memory that are available, and we describe the hardware of the input/output section, including the difference between the discrete and analog types of modules.

2.1 The I/O Section

The **input/output (I/O)** section of a PLC is the section to which all field devices are connected and provides the interface between them and the CPU. Input/output arrangements are built into a fixed PLC while modular types use external I/O modules that plug into the PLC.

Figure 2-1 illustrates a rack-based I/O section made up of individual I/O modules. Input interface modules accept signals from the machine or process devices and convert them into signals that can be used by the controller. Output interface modules convert controller signals into external signals used to control the machine or process. A typical PLC has room for several I/O modules, allowing it to be customized for a particular application by selecting the appropriate modules. Each slot in the rack is capable of accommodating any type of I/O module.

The I/O system provides an interface between the hardwired components in the field and the CPU. The input interface allows *status information* regarding processes to be communicated to the CPU, and thus allows the CPU to communicate *operating signals* through the output interface to the process devices under its control.

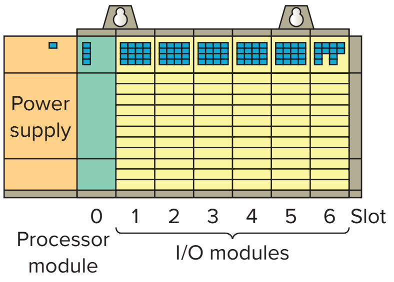


Figure 2-1 Rack-based I/O section.

One benefit of a PLC system is the ability to locate the I/O modules near the field devices, as illustrated in Figure 2-2, in order to minimize the amount of wiring required. The processor receives signals from the remote input modules and sends signals back to their output modules via the communication module.

A rack is referred to as a ***remote*** rack when it is located away from the processor module. To communicate with the processor, the remote rack uses a special communications network. Each remote rack requires a unique station number to distinguish one from another. The remote racks are linked to the local rack through a ***communications module***. Cables connect the modules with each other. If fiber optic cable is used between the CPU and I/O rack, it is possible to operate I/O points from distances greater than 20 miles with no voltage drop. Coaxial cable will allow remote I/O to be installed at distances greater than two miles. Fiber optic cable will not pick up noise caused by adjacent high power lines or equipment normally found in an industrial environment. Coaxial cable is more susceptible to this type of noise.

The PLC's memory system stores information about the status of all the inputs and outputs. To keep track of all this information, it uses a system called *addressing*. An **address** is a label or number that indicates where a certain piece of information is located in a PLC's memory. Just as your home address tells where you live in your city, a device's or a piece of data's address tells where

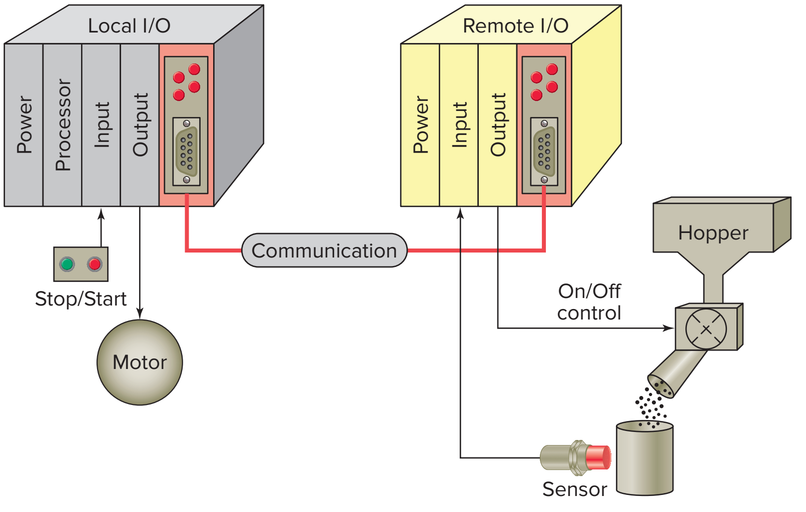


Figure 2-2 Remote I/O rack.

information about it resides in the PLC's memory. That way, if a PLC wants to find out information about a field device, it knows to look in its corresponding address location. Examples of addressing schemes include ***rack/slot-based***, versions of which are used in Allen-Bradley SLC 500 controllers, ***tag-based*** used in Allen-Bradley ControlLogix controllers, and PC-based control used in soft PLCs.

In general, rack/slot-based addressing elements include:

Type—The type determines if an input or output is being addressed.

Slot—The slot number is the physical location of the I/O module. This may be a combination of the rack number and the slot number when using expansion racks.

Word and Slot—The word and slot are used to identify the actual terminal connection in a particular I/O module. A discrete module usually uses only one word, and each connection corresponds to a different bit that makes up the word.

With a rack/slot address system the location of a module within a rack and the terminal number of a module to which an input or output device is connected will determine the device's address.

Figure 2-3 illustrates the Allen-Bradley **SLC 500** controller rack/slot addressing format. The address is used by the processor to identify where the device is located to monitor or control it. In addition, there is some means of connecting field wiring on the I/O module housing. Connecting the field wiring to the I/O housing allows easier disconnection and reconnection of the wiring to change modules. Lights are also added to each module to indicate the ON or OFF status of each I/O circuit. Most output modules also have blown fuse indicators. The following are typical examples of SLC 500 real-world general input and output addresses:

O:4/15	**Output module in slot 4, terminal 15**
I:3/8	**Input module in slot 3, terminal 8**
O:6.0	**Output module, slot 6**
I:5.0	**Input module, slot 5**

Every input and output device connected to a discrete I/O module is addressed to a specific ***bit*** in the PLC's memory. A bit is a binary digit that can be either 1 or 0. Analog I/O modules use a ***word*** addressing format, which allows the entire words to be addressed. The bit part of the address is usually not used; however, bits of the digital representation of the analog value can be addressed by the programmer if necessary. Figure 2-4 illustrates bit level and word level addressing as it applies to an SLC 500 controller.

Tag-based memory structures are the newest type of PLC memory addressing. Figure 2-5 illustrates the Allen-Bradley ControlLogix and CompactLogix tag-based addressing format. Memory locations are defined by using base and alias tags. A **base tag** defines a memory location where data are stored. An **alias tag** is used to create an alternate name (alias) for a tag. The alias tag is often used to create a tag name to represent a real world input or output.

Figure 2-6 shows a comparison between rack/slot-based addressing and tag-based addressing. Input and output modules, when configured, automatically create their own tags like Local:1:I.Data.1. Tag names are descriptive to the data being stored in them. The alias tag lets you use names that are more meaningful for the application. In this example:

- Pressure_switch is used instead of I:1/1
- Temperature_switch is used instead of I:1/2
- Manual_pushbutton is used instead of I:1/3
- Mixer_motor is used instead of O:2/1

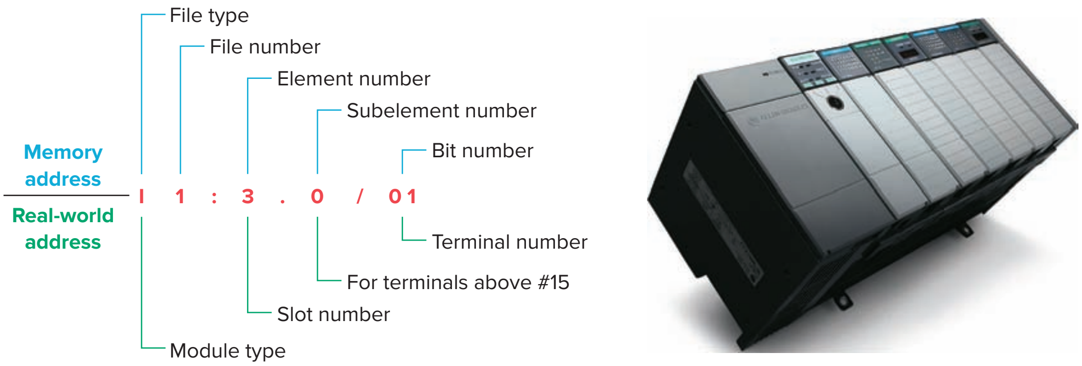


Figure 2-3 Allen-Bradley SLC 500 rack/slot-based addressing format.
Source: Image Courtesy of Rockwell Automation, Inc.

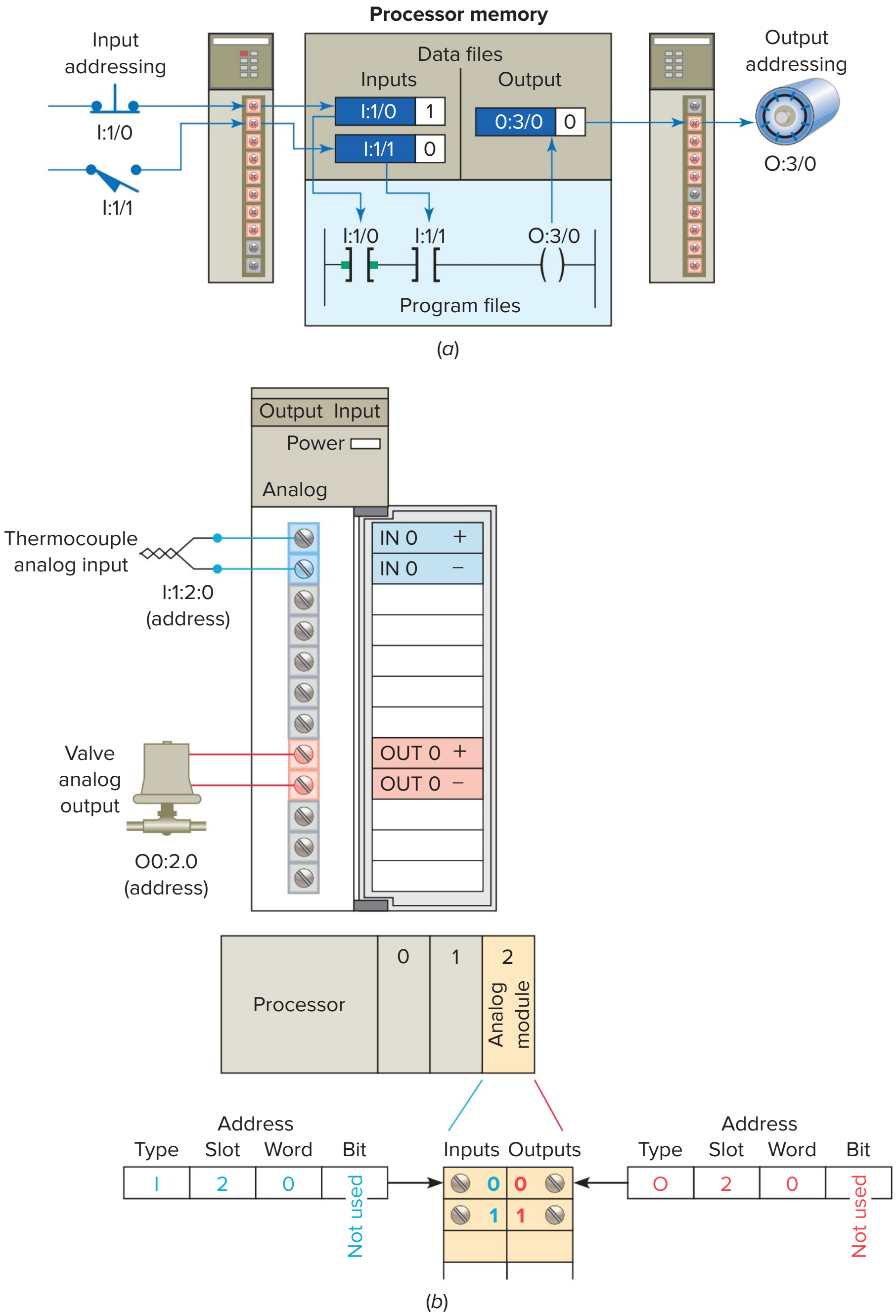
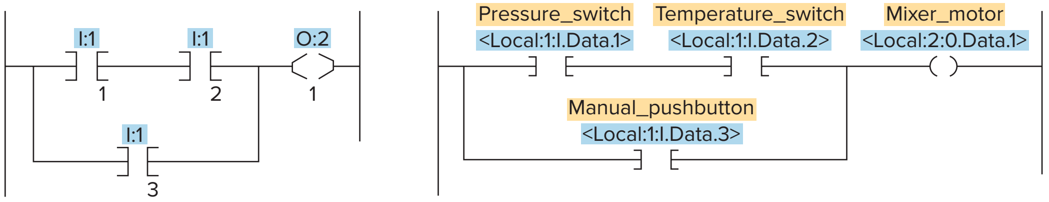


Figure 2-4 SLC 500 bit level and word level addressing. (*a*) Bit level addressing. (*b*) Word level addressing.

Figure 2-5 Allen-Bradley ControlLogix tag-based addressing format.
Source: Image Courtesy of Rockwell Automation, Inc.



(*a*) SLC 500 rack/slot-based addressing (*b*) Equivalent ControlLogix 5000 tag-base addressing

Figure 2-6 Rack/slot-based versus tag-based addressing.

PC-based control runs on personal or industrial hardened computers. Also known as soft PLCs, they simulate the functions of a PLC on a PC, allowing open architecture systems to replace proprietary PLCs. This implementation uses an input/output card (Figure 2-7) in conjunction with the PC as an interface for the field devices.

Combination I/O modules can have both input and output connections in the same physical module as illustrated in Figure 2-8. A module is made up of a printed circuit board and a terminal assembly. The printed circuit board contains the electronic circuitry used to interface the circuit of the processor with that of the input or output device. Modules are designed to plug into a slot or connector in the I/O rack or directly into the processor. The terminal assembly, which is attached to the front edge of the printed circuit board, is used for making field-wiring connections. Modules contain terminals for each input and output connection, status lights for each of the inputs and outputs, and connections to the power supply used to

Figure 2-7 Typical PC interface card.
Source: Photo © Beckhoff Automation GmbH & Co. KG.

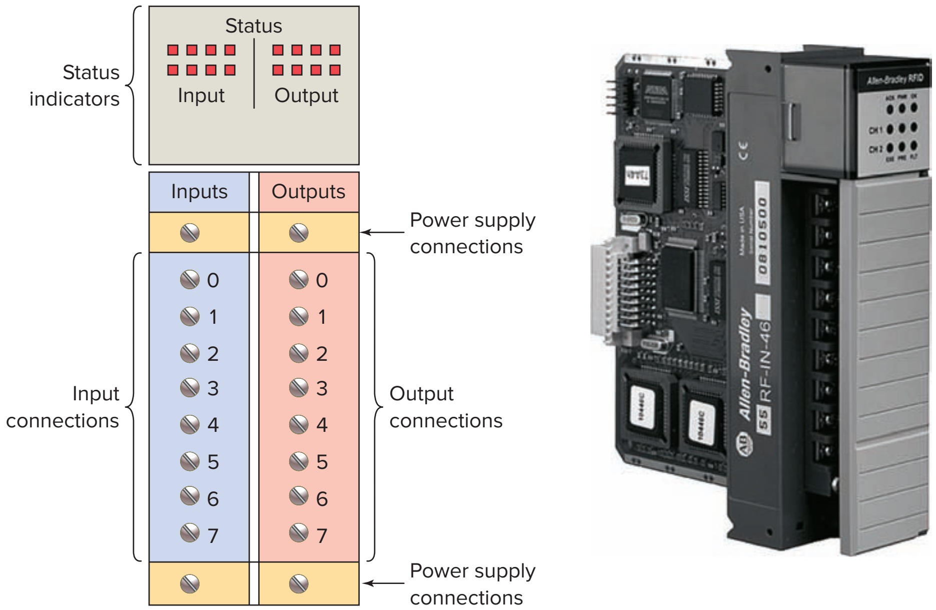


Figure 2-8 Typical combination I/O module.
Source: Image Courtesy of Rockwell Automation, Inc.

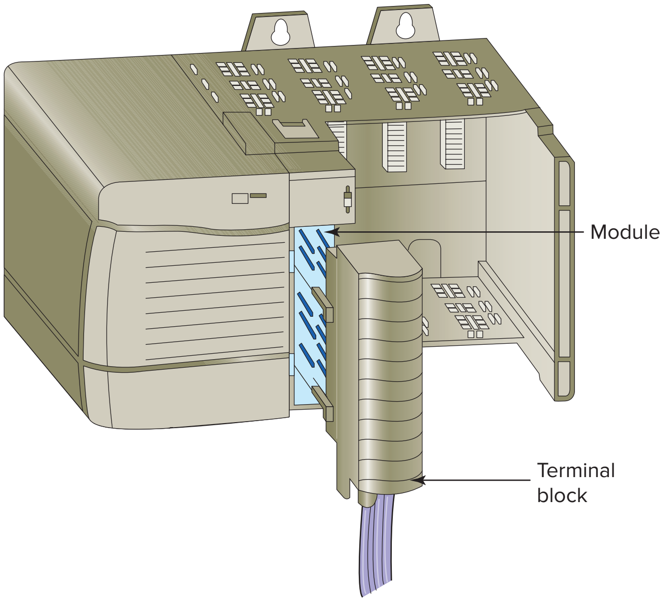


Figure 2-9 Plug-in terminal block.

power the inputs and outputs. Terminal and status light arrangements vary with different manufacturers.

Most PLC modules have plug-in wiring terminal strips. The terminal block is plugged into the actual module as illustrated in Figure 2-9. If there is a problem with a module, the entire strip is removed, a new module is inserted, and the terminal strip is plugged into the new module. Unless otherwise specified, never install or remove I/O modules or terminal blocks while the PLC is powered. A module inserted into the wrong slot could be damaged by improper voltages connected through the wiring arm. Most faceplates and I/O modules are keyed to prevent putting the wrong faceplate on the wrong module. In other words, an output module cannot be placed in the slot where an input module was originally located.

Input and output modules can be placed anywhere in a rack, but they are normally grouped together for ease of wiring. I/O modules can be 8, 16, 32, or 64 point cards (Figure 2-10). The number refers to the number of inputs or outputs available. The standard I/O module has eight inputs or outputs. A ***high-density*** module may have up to 64 inputs or outputs. The advantage with the high-density module is that it is possible to install up to 64 inputs or outputs in one slot for greater space savings. The only disadvantage is that the high-density output modules cannot handle as much current per output.

2.2 Discrete I/O Modules

The most common type of I/O interface module is the ***discrete*** type (Figure 2-11). 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 2-1.

The modules themselves receive their voltage and current for proper operation from the backplane of the rack enclosure into which they are inserted, as illustrated in Figure 2-12. **Backplane** power is provided by the PLC module power supply and is used to power the electronics that reside on the I/O module circuit board. The relatively higher currents required by the loads of an output module are normally provided by user-supplied power. Module power supplies typically may be rated for 3 A, 4 A, 12 A, or 16 A depending on the type and number of modules used.

Figure 2-10 16, 32, and 64 point I/O modules.
Source: (*all*) Photos courtesy Omron Industrial Automation, **www.ia.omron.com.**

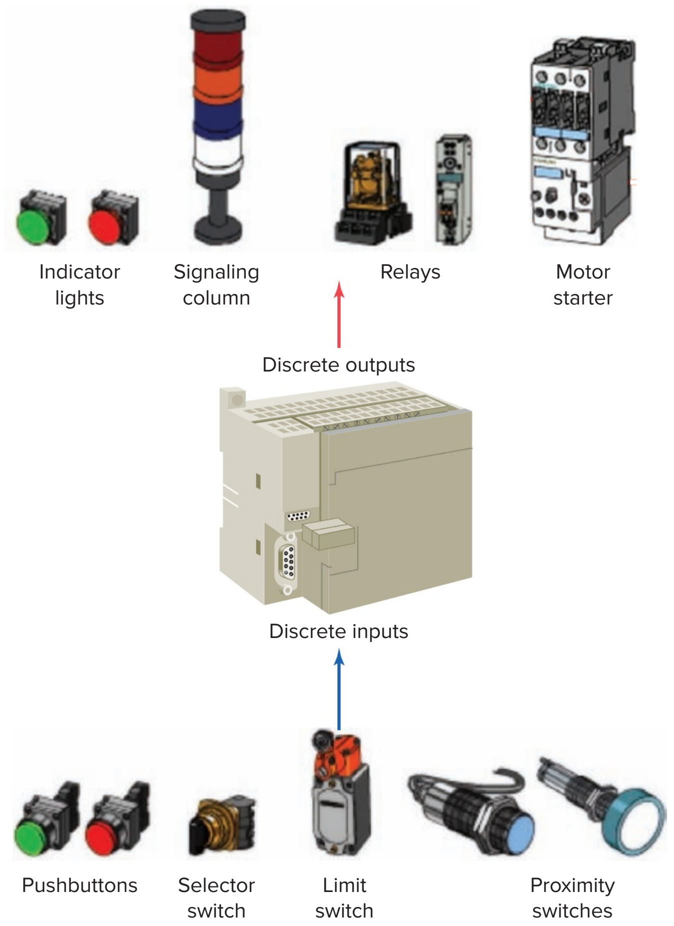


Figure 2-11 Discrete input and output devices.

Table 2-1 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**

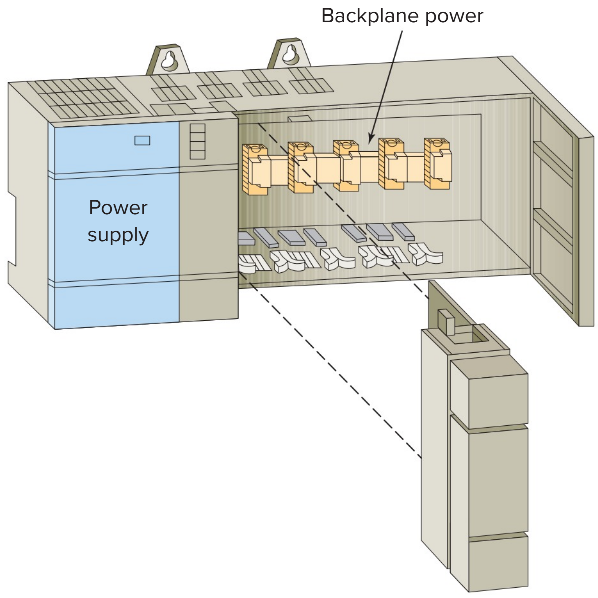


Figure 2-12 Modules receive their voltage and current from the backplane.

Figure 2-13 shows the block diagrams for one input of a typical alternating current (AC) *discrete input module.* The input circuit 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.

A simplified diagram for a single input of a discrete AC input module is shown in Figure 2-14. 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.

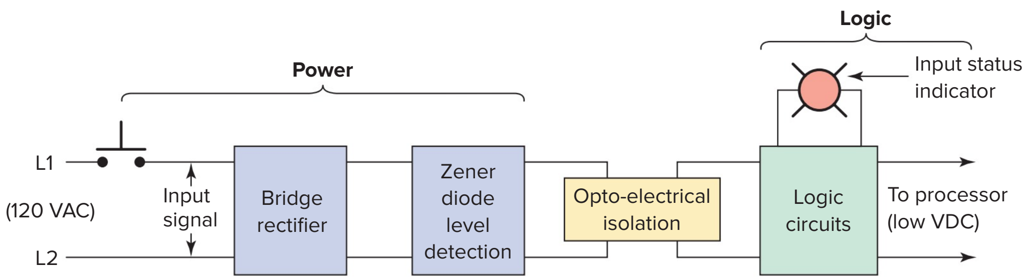


Figure 2-13 Discrete AC input module block diagram.

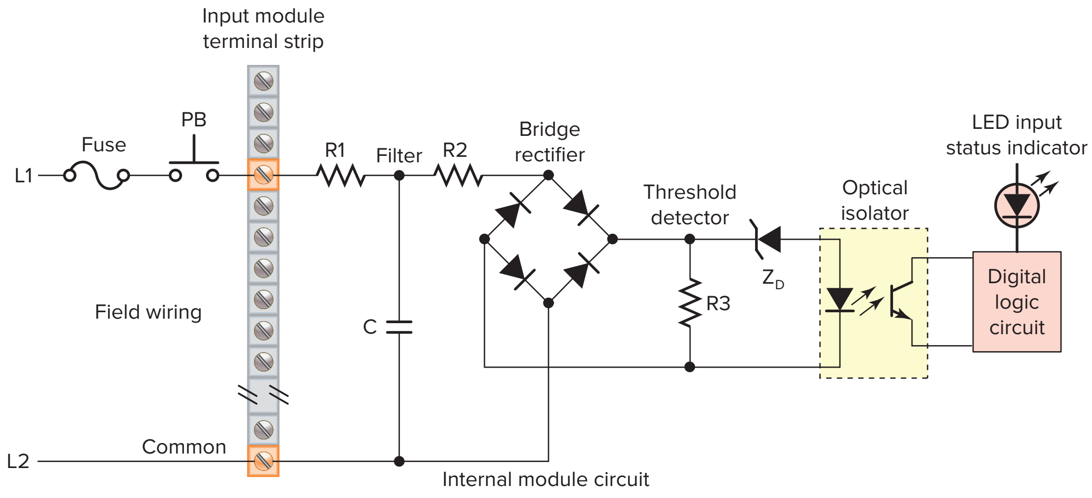


Figure 2-14 Simplified diagram for a single input of a discrete AC input module.

- 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. In addition, this isolation also helps reduce the effects of electrical noise, common in the industrial environment, which can cause erratic operation of the processor.
- 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.
- A PLC input module will have either all inputs isolated from each other with no common input connections or groups of inputs that share a common connection.

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 sensor originated the signal.

Figure 2-15 shows the block diagram for one output of a typical discrete output module. Like the input module, it is composed of two basic sections: the power section and the logic section, coupled by an isolation circuit. The output interface can be thought of as an electronic switch that turns the output load device on and off. Logic circuits determine the output status. An output LED indicates the status of the output signal.

A simplified diagram for a single output of a discrete AC output module is shown in Figure 2-16. The operation of the circuits . . . .set can be summarized as follows:

- As part of its normal operation, the digital logic circuits . . . .set of the processor sets the output status according to the program.

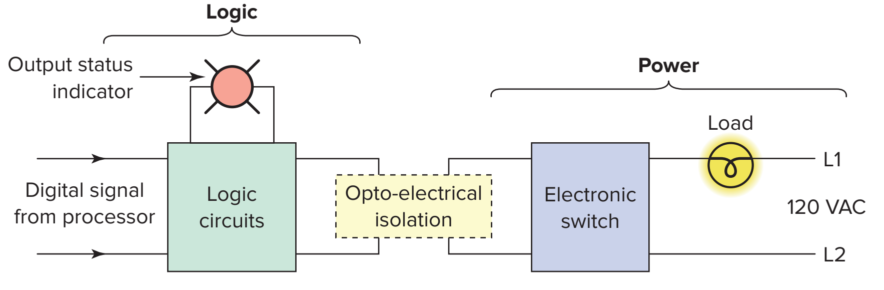


Figure 2-15 Discrete AC output module block diagram.

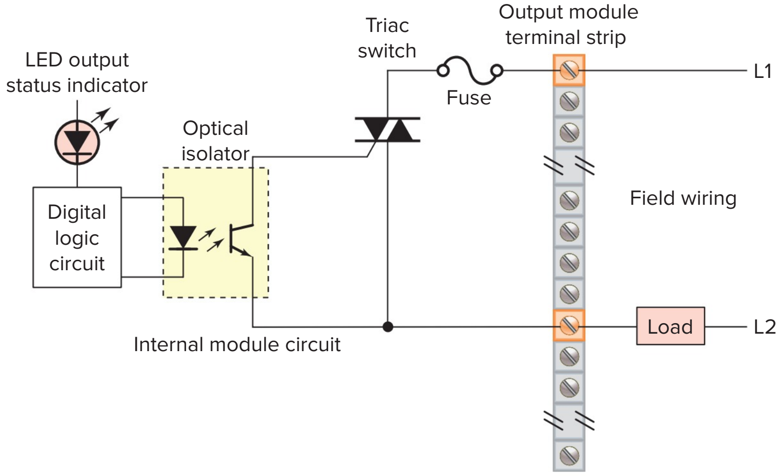


Figure 2-16 Simplified diagram for a single output of a discrete AC output module.

- 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 flow 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 milliamperes 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. Some modules also provide visual indicators for fuse status.
- The triac cannot be used to switch a DC load.
- For fault diagnosis, the LED output status indicator is on whenever the PLC is commanding that the output load be switched on.

Individual AC outputs are usually limited by the size of the triac to 1 A or 2 A. The maximum current load for any one module is also specified. To protect the output module circuits, specified current ratings should not be exceeded. For controlling larger loads, such as large motors, a standard control relay is connected to the output module. The contacts of the relay can then be used to control a larger load or motor starter, as shown in Figure 2-17. When a control relay is used in this manner, it is called an ***interposing* relay.**

Discrete output modules are used to turn field output devices either on or off. These modules can be used to control any two-state device, and they are available in AC and DC versions and in various voltage ranges and current ratings. Output modules can be purchased with *transistor, triac,* or *relay* output as illustrated in Figure 2-18. Triac outputs can be used only for control of AC devices,

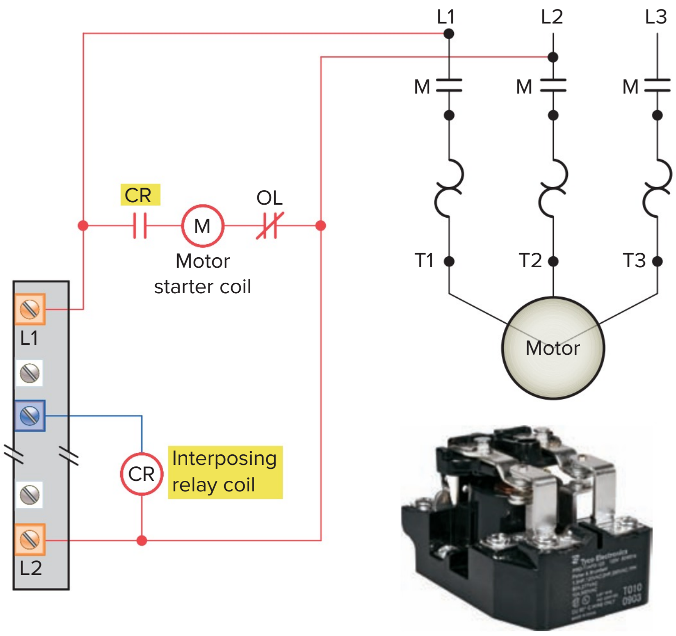


Figure 2-17 Interposing relay connection.
Source: Courtesy Tyco Electronics Ltd.

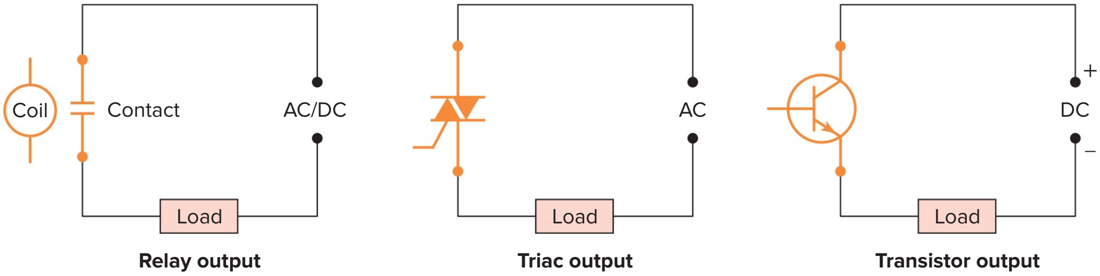


Figure 2-18 Relay, transistor, and triac switching elements.

whereas transistor outputs can be used only for control of DC devices. The discrete relay contact output module uses electromechanical as the switching element. These relay outputs can be used with AC or DC devices, but they have a much slower switching time compared to solid-state outputs. Allen-Bradley modules are color-coded for identification as follows:

Color	Type of I/O
Red	AC inputs/outputs
Blue	DC inputs/outputs
Orange	Relay outputs
Green	Specialty modules
Black	I/O wiring; terminal blocks are not removable

Certain DC I/O modules specify whether the module is designed for interfacing with current-source or current-sink devices. If the module is a current-sourcing module, then the input or output device must be a current-sinking device. Conversely, if the module is specified as current-sinking, then the connected device must be current-sourcing. Some modules allow the user to select whether the module will act as current sinking or current sourcing, thereby allowing it to be set to whatever the field devices require. Sinking and sourcing terminology applies only to DC input and output circuits.

Allen-Bradley delineates between the various digital DC modules by sorting them into two categories: **Sinking** and **Sourcing.** These terms are used to describe a current signal flow relationship between field input and output devices. If a device provides current when it is ON, it is said to be sourcing current. Conversely, if a device receives current when it is ON, it is said to be sinking current.

Figures 2-19 and 2-20 show device connections for both sourcing and sinking configurations:

- Conventional current (+ to −) is assumed.
- In sinking devices, current flows into the device's terminal from the module (the module provides, or sources the current).
- In sourcing devices, current flows out of the device's terminal into the module (the module receives, or sinks, the current).
- A sourcing I/O device or I/O module will always have a connection directly to the positive side of the DC power supply.
- A sinking I/O device or I/O module will always have a connection directly to the negative side of the DC power supply.

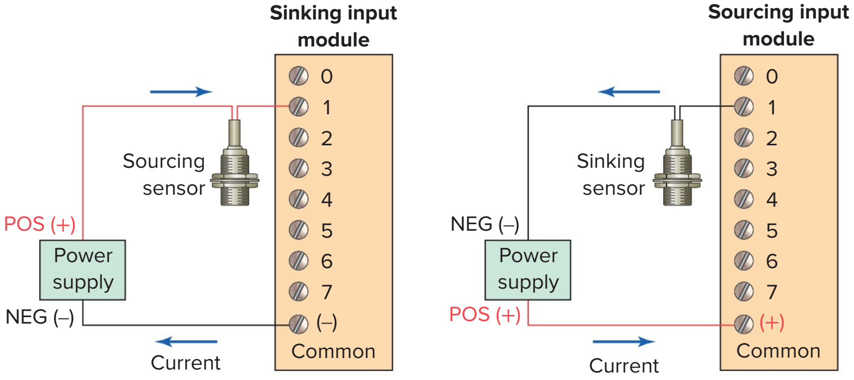


Figure 2-19 Sinking and sourcing inputs.

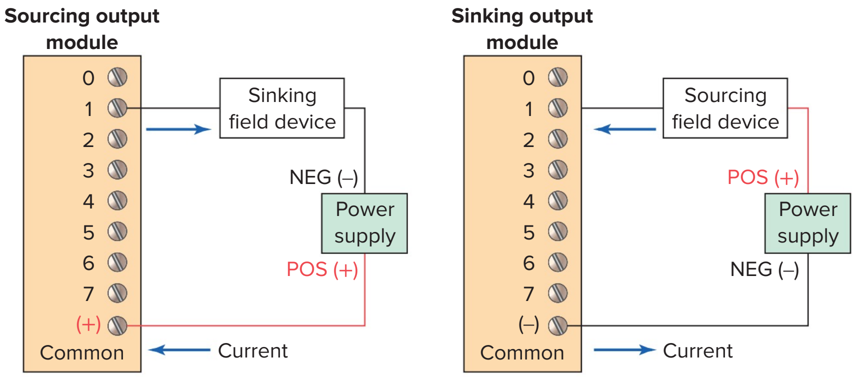


Figure 2-20 Sinking and sourcing outputs.

- Input and output points that are sinking or sourcing only can conduct current in only one direction. Therefore, it is possible to connect the external supply and field device to the I/O point with current trying to flow in the wrong direction, and the circuit **will not operate.**

2.3 Analog I/O Modules

Earlier PLCs were limited to discrete or digital I/O interfaces, which allowed only on/off-type devices to be connected. This limitation meant that the PLC could have only partial control of many process applications. Today, however, a complete range of both discrete and analog interfaces are available that will allow controllers to be applied to practically any type of control process.

Discrete devices are inputs and outputs that have only two states: on and off. In comparison, **analog** devices represent physical quantities that can have an infinite number of values. Typical analog inputs and outputs vary from 0 to 20 mA, 4 to 20 mA, or 0 to 10 V. Figure 2-21 illustrates how PLC analog input and output modules are used in measuring and displaying the level of fluid in a tank. The analog input interface module contains the circuitry necessary to accept an analog voltage or current signal from the level transmitter field device. This input is converted from an analog to a digital value for use by the processor. The circuitry of the analog output module accepts the digital value from the processor and converts it back to an analog signal that drives the field tank level meter.

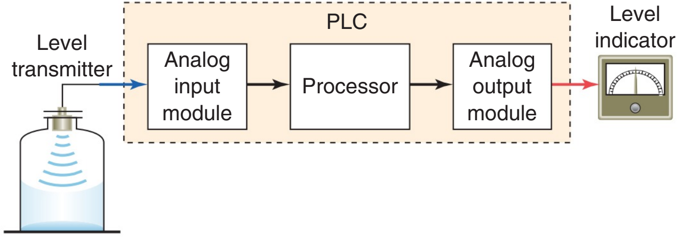


Figure 2-21 Analog input and output to a PLC.

Analog input modules normally have multiple input channels that allow 4, 8, or 16 devices to be interface to the PLC. The two basic types of analog input modules are ***voltage* sensing** and ***current* sensing.** Input modules have user-selectable dip switch settings to choose whether each input will be a current or voltage input. Analog sensors measure a varying physical quantity over a specific range and generate a corresponding voltage or current signal. Common physical quantities measured by a PLC analog module include temperature, speed, level, flow, weight, pressure, and position. For example, a sensor may measure temperature over a range of 0 to 500°C, and output a corresponding voltage signal that varies between 0 and 50 mV.

Figure 2-22 illustrates an example of a voltage sensing input analog module used to measure temperature. The connection diagram applies to an Allen-Bradley MicroLogic 4-channel analog thermocouple input module. A varying DC voltage in the low millivolt range, proportional to the temperature being monitored, is produced by the thermocouple. This voltage is amplified and digitized by the analog input module and then sent to the processor on command from a program instruction. Because of the low voltage level of the input signal, a twisted shielded pair cable is used in wiring the circuit to reduce unwanted electrical noise signals that can be induced in the conductors from other wiring. When using an ungrounded thermocouple, the shield must be connected to ground at the module end. To obtain accurate readings from each of the channels, the temperature between the thermocouple wire and the input channel must be compensated for. A cold junction compensating (CJC) thermistor is integrated in the terminal block for this purpose.

The transition of an analog signal to digital values is accomplished by an analog-to-digital (A/D) converter, the main element of the analog input module. Analog voltage input modules are available in two types: unipolar

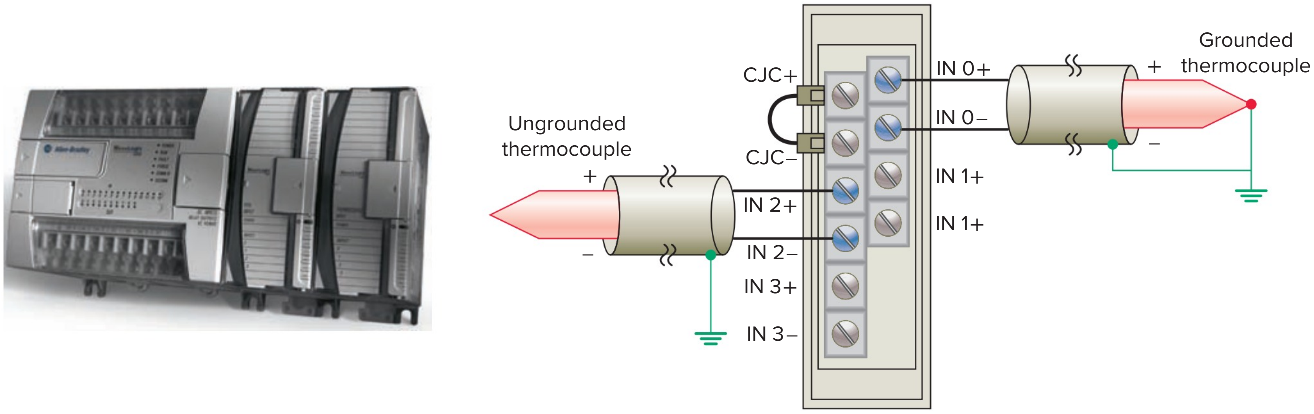


Figure 2-22 MicroLogix 4-channel analog thermocouple input module.
Source: Image Courtesy of Rockwell Automation, Inc.

and bipolar. ***Unipolar*** modules can accept an input signal that varies in the positive direction only. For example, if the field device outputs 0 to +10 V, then the unipolar modules would be used. Bipolar signals swing between a maximum negative value and a maximum positive value. For example, if the field device outputs −10 to +10 V a bipolar module would be used. The ***resolution*** of an analog input channel refers to the smallest change in input signal value that can be sensed and is based on the number of bits used in the digital representation. Analog input modules must produce a range of digital values between a maximum and minimum value to represent the analog signal over its entire span. Typical specifications are as follows:

Span of analog input	Bipolar	10 V	−10 to +10 V
		5 V	−5 to +5 V
	Unipolar	10 V	0 to +10 V
		5 V	0 to +5 V
Resolution			0.3 mV

When connecting voltage sensing inputs, close adherence to specified requirements regarding wire length is important to minimize signal degrading and the effects of electromagnetic noise interference induced along the connecting conductors. Current input signals, which are not as sensitive to noise as voltage signals, are typically not distance limited. Current sensing input modules typically accept analog data over the range of 4 to 20 mA, but can accommodate signal ranges of –20 to +20 mA. The loop power may be supplied by the sensor or may be provided by the analog output module as illustrated in Figure 2-23. Shielded twisted pair cable is normally recommended for connecting any type of analog input signal.

Field devices that provide an analog output as their signal are usually connected to transmitters, which in turn send the analog signal to the module, as illustrated in Figure 2-24. A **transducer** converts a field device's variable (e.g., pressure, temperature etc.) into a very low-level electric signal (current or voltage) that can be amplified by a **transmitter** and then input into the analog module.

The method user to wire two-, three-, and four-wire sensors to an analog input module is illustrated in Figure 2-25. The module does not provide loop power for analog inputs. A separate power that matches the transmitter specifications is used. All analog common

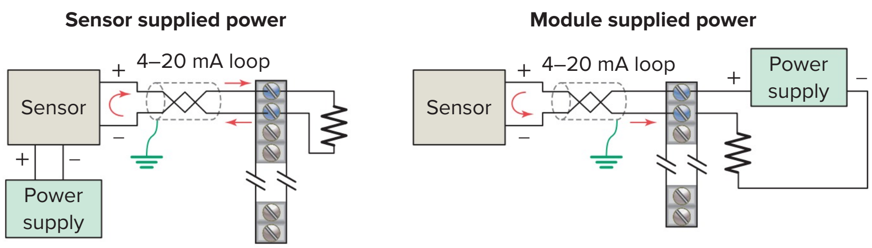


Figure 2-23 Sensor and analog module supplied power.

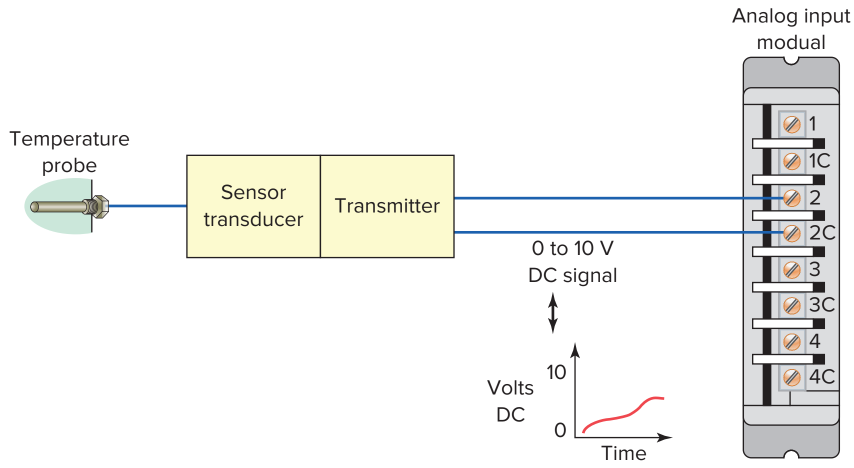


Figure 2-24 Analog input module circuit.

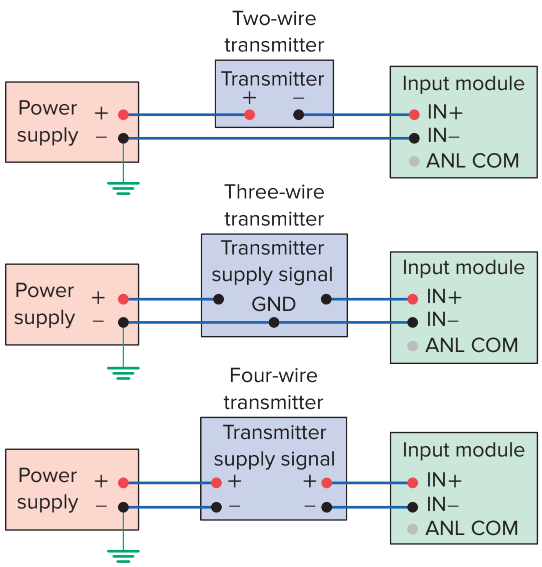


Figure 2-25 Wiring two-, three-, and four-wire sensors to an analog input module.

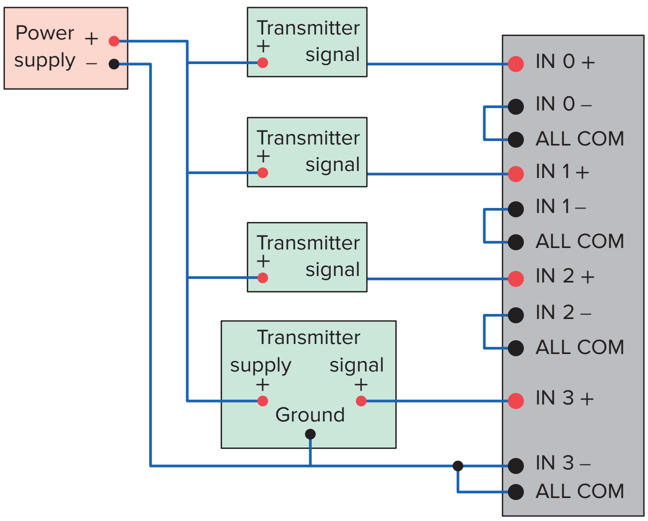


Figure 2-26 Wiring single-ended analog input devices.

(ANL COM) points are electrically connected together inside the module but not to earth ground. When wiring single-ended analog input devices to the analog input card, the number of total wires necessary can be limited by using the ANALOG COMMON terminal, as shown in Figure 2-26. Note that differential inputs are more immune to noise than single-ended inputs.

The ***analog output interface module*** receives from the processor digital data, which are converted into a proportional voltage or current to control an analog field device. The transition of a digital signal to analog values is accomplished by a **digital-to-analog (D/A)** converter, the main element of the analog output module. An analog output signal is a continuous and changing signal that is varied under the control of the PLC program. Common devices controlled by a PLC analog output module include instruments, control valves, chart recorder, electronic drives, and other types of control devices that respond to analog signals. They employ standard analog output ranges such as ±5 V, ±10 V, 0 to 5 V, 0 to 10 V, 4 to 20 mA, or 0 to 20 mA.

Figure 2-27 illustrates the use of analog I/O modules in a typical PLC control system. In this application the

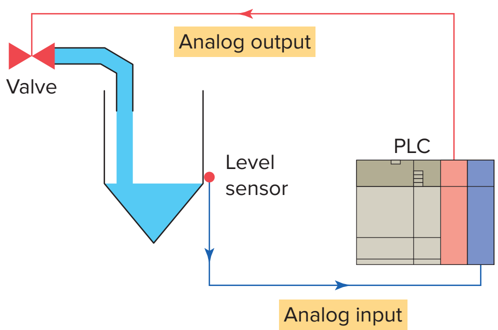


Figure 2-27 Typical analog I/O control system.

PLC controls the amount of fluid placed in a holding tank by adjusting the percentage of the valve opening. The analog output from the PLC is used to control the flow by controlling the amount of the valve opening. The valve is initially open 100%. As the fluid level in the tank approaches the preset point, the processor modifies the output, which adjusts the valve to maintain a set point.

Transducers produce either voltage or current proportional to some engineering units such as temperature (°C or °F), pressure (lb/in^2), distance (cm), etc. **Scaling** refers to changing a quantity from one notation to another and involves:

Engineering units: The units a human uses and understands

Transducer units: Either a voltage or current

Binary, raw, or machine units: The units the processor requires

The SCP (Scale with Parameters) instruction in RSLogix 500 is used to produce a scaled output value that has a linear relationship between the input and scaled values. It allows you to take an analog input from a sensor and scale it to the output units you require. Figure 2-28 illustrates a typical application involving temperature measurement. Setting up the SCP instruction to calculate the scaled temperature value in degrees Celsius can be summarized as follows:

- The *Input* parameter is the value to be scaled (in this case analog input I:1.1)
- The *Input Min* parameter is the value that is read by the analog card when the input is − 10V (in this case −32768)
- The *Input Max* parameter is the value that is read by the analog card when the input is 10V (in this case 32767)
- The *Scaled Min* parameter is the lowest value you want the SCP to calculate (in this case −100)
- The *Scaled Max* parameter is the highest value you want the SCP to calculate (in this case 200)
- The *Scaled Output* parameter is the address where you want to store the result of the SCP (in this case N7:60)

The SCP instruction in Figure 2-29 is used to scale the analog output to a proportional valve. The instruction directs the analog output to provide a 4 to 20mA signal, which is scaled to the valve position based on a percentage between 0 and 100. The module is scaled to represent 4 mA as the low signal and 20 mA as the high signal.

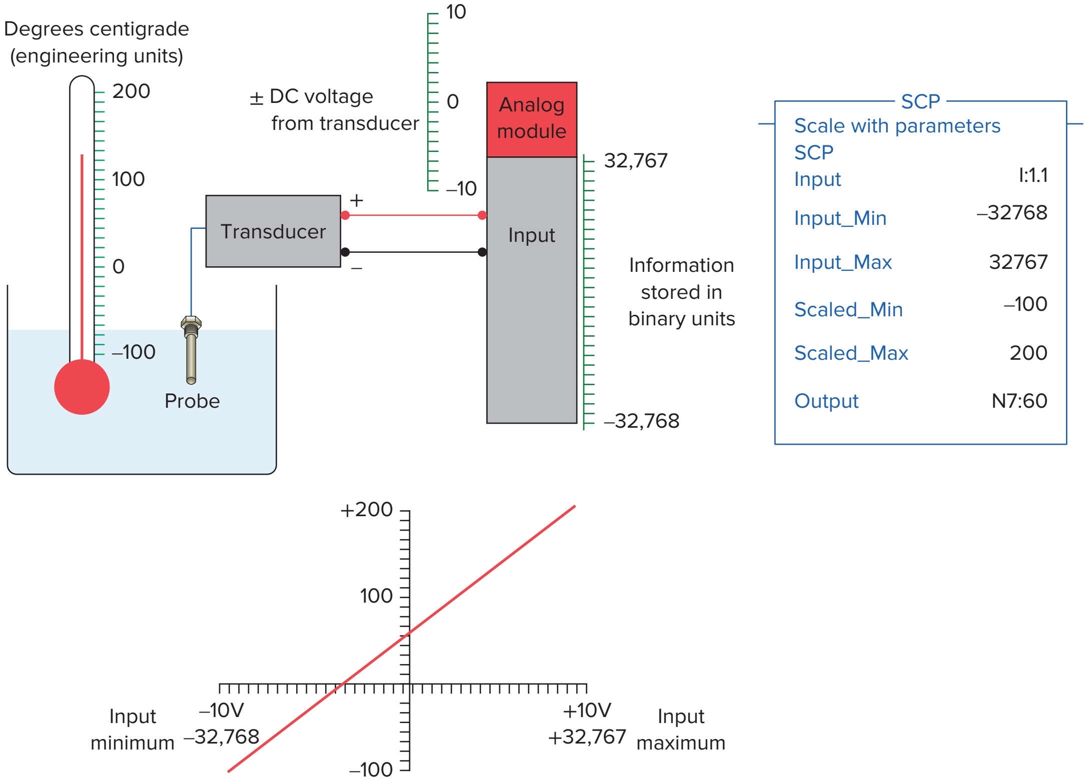


Figure 2-28 Measuring temperature.

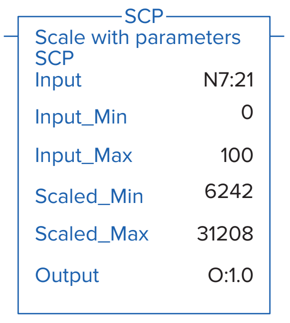


Figure 2-29 Scaling the analog output to a proportional valve.

Scaling allows you to configure the module so that 4 mA returns a value of 0% in engineering units and 20 mA returns a value of 100% in engineering units. The execution of the instruction can be summarized as follows:

- The proportional valve is connected to the PLC output O:1.0.
- A 4 to 20 mA signal varies in magnitude to operate the valve from closed to 100% open.
- The percent of the valve open can be found in location N7:21.
- The PLC analog module provides a 4 to 20 mA output signal for a number from 6,242 to 31,208.

Figure 2-31 Thumbwheel switch.
Source: Photo courtesy Omron Industrial Automation, **www.ia.omron.com.**

2.4 Special I/O Modules

Many different types of I/O modules have been developed to meet special needs. These include:

HIGH-SPEED COUNTER MODULE

The high-speed counter module is used to provide an interface for applications requiring counter speeds that surpass the capability of the PLC ladder program. High-speed counter modules are used to count pulses (Figure 2-30) from sensors, encoders, and switches that operate at very high speeds. They have the electronics needed to count independently of the processor. A typical count rate available is 0 to 100 kHz, which means the module would be able to count 100,000 pulses per second.

THUMBWHEEL MODULE

The thumbwheel module allows the use of thumbwheel switches (Figure 2-31) for feeding information to the PLC to be used in the control program.

TTL MODULE

The TTL module allows the transmitting and receiving of TTL (Transistor-Transistor-Logic) signals. This module allows devices that produce TTL-level signals to communicate with the PLC's processor.

ENCODER-COUNTER MODULE

An encoder-counter module allows the user to read the signal from an encoder (Figure 2-32) on a real-time basis and stores this information so it can be read later by the processor.

BASIC OR ASCII MODULE

The BASIC or ASCII module runs user-written BASIC and C programs. These programs are independent of the PLC processor and provide an easy, fast interface between remote foreign devices and the PLC processor. Typical applications include interfaces to bar code readers, robots, printers, and displays.

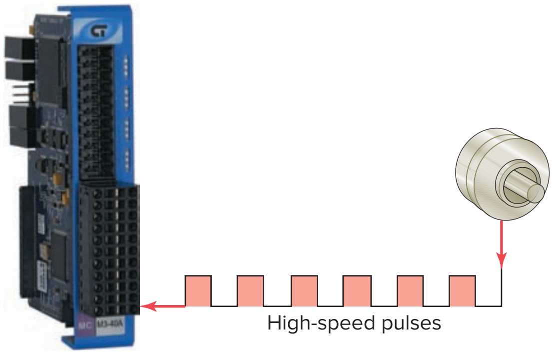


Figure 2-30 High-speed counter module.
Source: Courtesy Control Technology Corporation.


Figure 2-32 Encoder.
Source: Photo courtesy of Allied Motion Technologies, Inc.

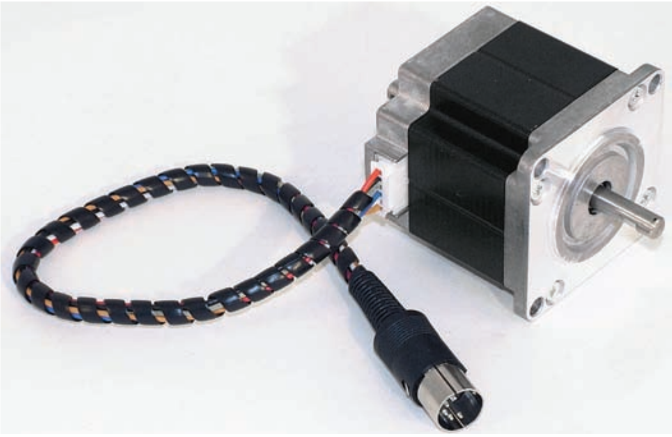


Figure 2-33 Stepper-motor.
Source: Courtesy Sherline Products.

Figure 2-35 PID module.
Source: Courtesy Red Lion Controls.

STEPPER-MOTOR MODULE

The stepper-motor module provides pulse trains to a stepper-motor translator, which enables control of a stepper motor (Figure 2-33). The commands for the module are determined by the control program in the PLC.

BCD-OUTPUT MODULE

The BCD-output module enables a PLC to operate devices that require BCD-coded signals such as seven-segment displays (Figure 2-34).

Some special modules are referred to as *intelligent I/O* because they have their own microprocessors on board that can function in parallel with the PLC. These include:

PID MODULE

The proportional-integral-derivative (PID) module (Figure 2-35) is used in process control applications that incorporate PID algorithms. An algorithm is a complex program based on mathematical calculations. A PID module allows process control to take place outside the CPU. This arrangement prevents the CPU from being burdened with complex calculations. The basic function of this module is to provide the control action required to maintain a process variable such as temperature, flow, level, or speed within set limits of a specified set point.

MOTION AND POSITION CONTROL MODULE

Motion and position control modules are used in applications involving accurate high-speed machining and packaging operations. Intelligent position and motion control modules permit PLCs to control stepper and servo motors. These systems require a drive, which contains the power electronics that translate the signals from the PLC module into signals required by the motor (Figure 2-36).

COMMUNICATION MODULES

Serial communications modules (Figure 2-37) are used to establish point-to-point connections with other intelligent devices for the exchange of data. Such connections are normally established with computers, operator stations, process control systems, and other PLCs. Communication modules allow the user to connect the PLC to high-speed local networks that may be different from the network communication provided with the PLC.

Figure 2-34 Seven-segment display.
Source: Courtesy Red Lion Controls.

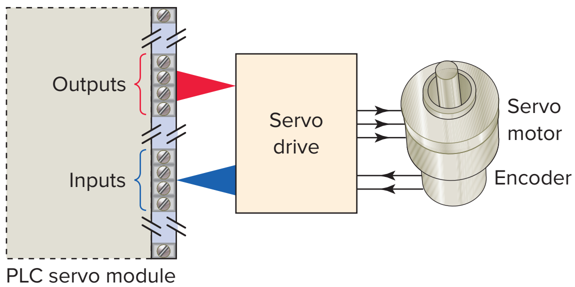


Figure 2-36 PLC servo module.

Figure 2-37 Serial communications module.
Source: Photo courtesy Automation Direct, **www.automationdirect.com.**

2.5 I/O Specifications

Manufacturers' specifications provide information about how an interface device is correctly and safely used. These specifications place certain limitations not only on the I/O module but also on the field equipment that it can operate. Some PLC systems support *hot swappable* I/O modules designed to be changed with the power on and the PLC operating. The following is a list of some typical manufacturers' I/O specifications, along with a short description of what is specified.

Typical Discrete I/O Module Specifications

NOMINAL INPUT VOLTAGE

This discrete input module voltage value specifies the magnitude (e.g., 5, 24, 230 V) and type (AC or DC) of user-supplied voltage that a module is designed to accept. Input modules are typically designed to operate correctly without damage within a range of plus or minus 10% of the input voltage rating. With DC input modules, the input voltage may also be expressed as an operating range (e.g., 24 to 60 V DC) over which the module will operate.

INPUT THRESHOLD VOLTAGES

This discrete input module specification specifies two values: a minimum ON-state voltage that is the minimum voltage at which logic 1 is recognized as absolutely ON; and a maximum OFF-state voltage which is the voltage at which logic 0 is recognized as absolutely OFF.

NOMINAL CURRENT PER INPUT

This value specifies the minimum input current that the discrete input devices must be capable of driving to operate the input circuit. This input current value, in conjunction with the input voltage, functions as a threshold to protect against detecting noise or leakage currents as valid signals.

AMBIENT TEMPERATURE RATING

This value specifies what the maximum temperature of the air surrounding the I/O modules should be for best operating conditions.

INPUT ON/OFF DELAY

Also known as *response time,* this value specifies the maximum time duration required by an input module's circuitry to recognize that a field device has switched ON (input ON-delay) or switched OFF (input OFF-delay). This delay is a result of filtering circuitry provided to protect against contact bounce and voltage transients. This input delay is typically in the 9 to 25 ms range.

OUTPUT VOLTAGE

This AC or DC value specifies the magnitude (e.g., 5 V, 115 V, 230 V) and type (AC or DC) of user-supplied voltage at which a discrete output module is designed to operate. The output field device that the module interfaces to the PLC must be matched to this specification. Output modules are typically designed to operate within a range of plus or minus 10% of the nominal output voltage rating.

OUTPUT CURRENT

These values specify the maximum current that a single output and the module as a whole can safely carry under load (at rated voltage). This rating is a function of the module's components and heat dissipation characteristics. A device drawing more than the rated output current results in overloading, causing the output fuse to blow. As an example, the specification may give each output a current limit of 1 A. The overall rating of the module current will normally be less than the total of the individuals. The overall rating might be 6 A because each of the eight devices would not normally draw their 1 A at the same time. Other names for the output current rating are *maximum continuous current* and *maximum load current.*

INRUSH CURRENT

An inrush current is a momentary surge of current that an AC or DC output circuit encounters when energizing inductive, capacitive, or filament loads. This value specifies the maximum inrush current and duration (e.g., 20 A for 0.1 s) for which an output circuit can exceed its maximum continuous current rating.

SHORT CIRCUIT PROTECTION

Short circuit protection is provided for AC and DC output modules by either fuses or some other current-limiting circuitry. This specification will designate whether the particular module's design has individual protection for each circuit or if fuse protection is provided for groups (e.g., 4 or 8) of outputs.

LEAKAGE CURRENT

This value specifies the amount of current still conducting through an output circuit even after the output has been turned off. Leakage current is a characteristic exhibited by solid-state switching devices such as transistors and triacs and is normally 1 to 2 mA. Leakage current is normally not large enough to falsely trigger an output device but must be taken into consideration when switching very low current sensitive devices.

ELECTRICAL ISOLATION

Recall that I/O module circuitry is electrically isolated to protect the low-level internal circuitry of the PLC from high voltages that can be encountered from field device connections. The specification for electrical isolation, typically 1500 or 2500 V AC, rates the module's capacity for sustaining an excessive voltage at its input or output terminals.

POINTS PER MODULE

This specification defines the number of field inputs or outputs that can be connected to a single module. Most commonly, a discrete module will have 8, 16, or 32 circuits; however, low-end controllers may have only 2 or 4 circuits. Modules with 32 or 64 input or output bits are referred to as *high-density* modules. Some modules provide more than one common terminal, which allows the user to use different voltage ranges on the same card as well as to distribute the current more effectively.

BACKPLANE CURRENT DRAW

This value indicates the amount of current the module requires from the backplane. The sum of the backplane current drawn for all modules in a chassis is used to select the appropriate chassis power supply rating.

Typical Analog I/O Module Specifications

CHANNELS PER MODULE

Whereas individual circuits on discrete I/O modules are referred to as points, circuits on analog I/O modules are often referred to as channels. These modules normally have 4, 8, or 16 channels. Analog modules may allow for either single-ended or differential connections. *Single-ended* connections use a single ground terminal for all channels or for groups of channels. *Differential* connections use a separate positive and negative terminal for each channel. If the module normally allows 16 single-ended connections, it will generally allow only 8 differential connections. Single-ended connections are more susceptible to electrical noise.

INPUT CURRENT/VOLTAGE RANGE(S)

These are the voltage or current signal ranges that an analog input module is designed to accept. The input ranges must be matched accordingly to the varying current or voltage signals generated by the analog sensors.

OUTPUT CURRENT/VOLTAGE RANGE(S)

This specification defines the current or voltage signal ranges that a particular analog output module is designed to output under program control. The output ranges must be matched according to the varying voltage or current signals that will be required to drive the analog output devices.

INPUT PROTECTION

Analog input circuits are usually protected against accidentally connecting a voltage that exceeds the specified input voltage range.

RESOLUTION

The resolution of an analog I/O module specifies how accurately an analog value can be represented digitally. This specification determines the smallest measurable unit of current or voltage. The higher the resolution (typically specified in bits or mV), the more accurately an analog value can be represented.

INPUT IMPEDANCE AND CAPACITANCE

For analog I/Os, these values must be matched to the external device connected to the module. Typical ratings are in Megohm (MΩ) and picofarads (pF).

COMMON-MODE REJECTION

Noise is generally caused by electromagnetic interference, radio frequency interference, and ground loops. Common-mode noise rejection applies only to differential inputs and refers to an analog module's ability to prevent noise from interfering with data integrity on a single channel and from channel to channel on the module. Noise that is picked up equally in parallel wires is rejected because the difference is zero. Twisted pair wires are used to ensure that this type of noise is equal on both wires. Common-mode rejection is normally expressed in decibels or as a ratio.

2.6 The Central Processing Unit (CPU)

The central processing unit (CPU) is built into single-unit fixed PLCs while modular rack types typically use a plug-in module. CPU, controller, and processor are all terms used by different manufacturers to denote the same module that performs basically the same functions. Processors vary in processing speed and memory options. A processor module can be divided into two sections: the **CPU section** and the **memory section** (Figure 2-38). The CPU section executes the program and makes the decisions needed by the PLC to operate and communicate with other modules. The memory section electronically stores the PLC program along with other retrievable digital information.

The PLC power supply provides the necessary power (typically 5 VDC) to the processor and I/O modules plugged into the backplane of the rack (Figure 2-39). Power supplies are available for most voltage sources encountered. The power supply converts 115 VAC or 230 VAC into the usable DC voltage required by the CPU, memory, and I/O electronic circuitry. PLC power supplies are normally designed to withstand momentary losses of power without affecting the operation of the PLC. *Hold-up time,* which is the length of time a PLC can tolerate a power loss, typically ranges from 10 ms to 3 s.

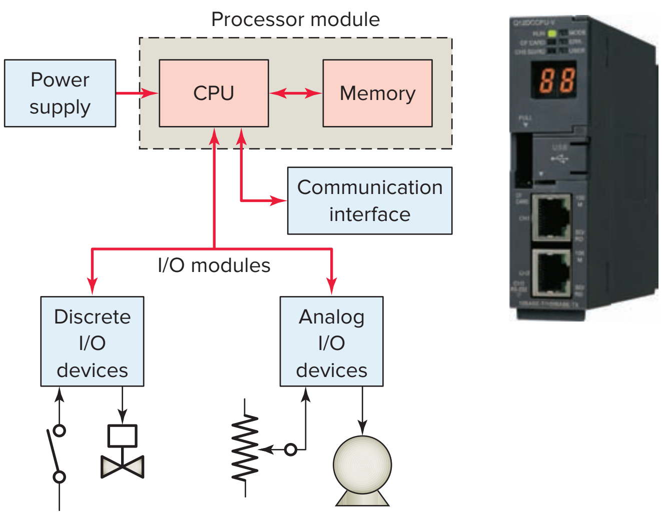


Figure 2-38 Sections of a PLC processor module.
Source: Courtesy Mitsubishi Automation.

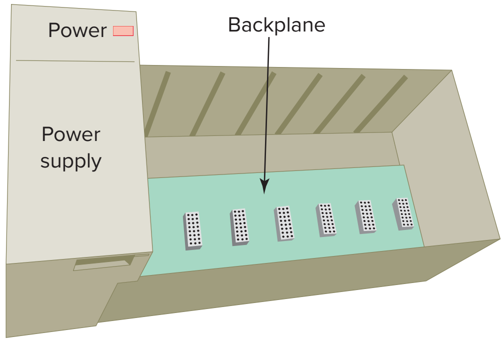


Figure 2-39 PLC power supply.

The CPU contains the similar type of microprocessor found in a personal computer. The difference is that the program used with the microprocessor is designed to facilitate industrial control rather than provide general-purpose computing. The CPU executes the operating system, manages memory, monitors inputs, evaluates the user logic (ladder program), and turns on the appropriate outputs.

The CPU of a PLC system may contain more than one processor. One advantage of using multiprocessing is that the overall operating speed is improved. Each processor has its own memory and programs, which operate simultaneously and independently. In such configurations the scan of each processor is parallel and independent thus reducing the total response time. Fault-tolerant PLC systems support dual processors for critical processes. These systems allow the user to configure the system with ***redundant*** (two) processors, which allows transfer of control to the second processor in the event of a processor fault.

Associated with the processor unit will be a number of status LED indicators to provide system diagnostic information to the operator (Figure 2-40). Also, a keyswitch may be provided that allows you to select one of the following three modes of operation: RUN, PROG, and REM.

RUN Position

- Places the processor in the Run mode
- Executes the ladder program and energizes output devices
- Prevents you from performing online program editing in this position
- Prevents you from using a programmer/operator interface device to change the processor mode

PROG Position

- Places the processor in the Program mode
- Prevents the processor from scanning or executing the ladder program, and the controller outputs are de-energized

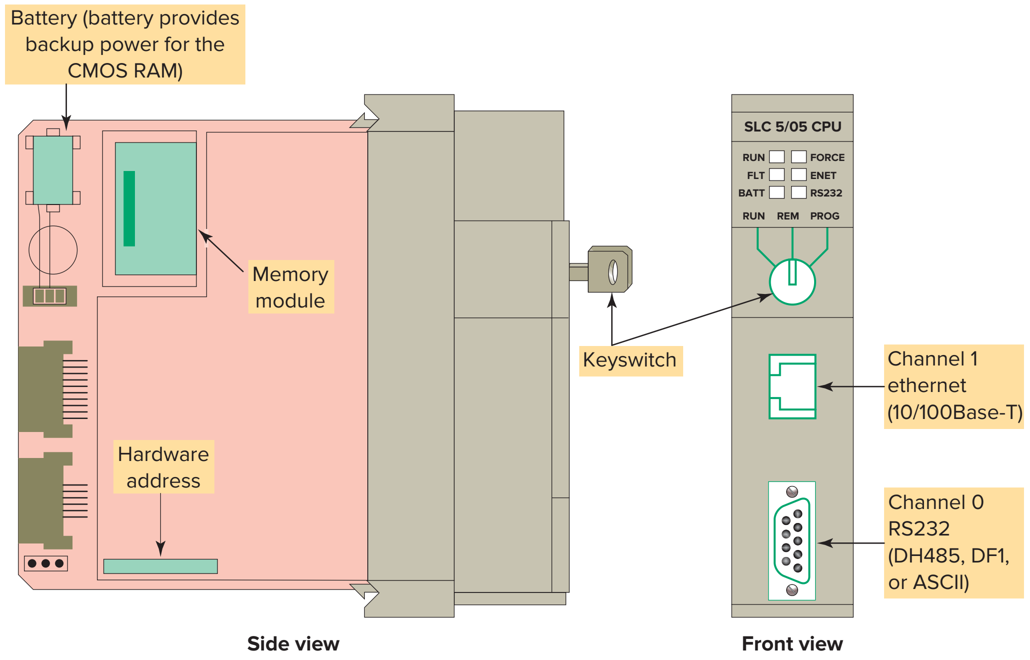


Figure 2-40 Typical processor module.

- Allows you to perform program entry and editing
- Prevents you from using a programmer/operator interface device to change the processor mode

REM Position

- Places the processor in the Remote mode: either the REMote Run, REMote Program, or REMote Test mode
- Allows you to change the processor mode from a programmer/operator interface device
- Allows you to perform online program editing

The processor module also contains circuitry to communicate with the programming device. Somewhere on the module you will find a connector that allows the PLC to be connected to an external programming device. The decision-making capabilities of PLC processors go far beyond simple logic processing. The processor performs other functions such as timing, counting, latching, comparing, motion control and complex math functions.

PLC processors have changed constantly due to advancements in computer technology and greater demand from applications. Today, processors are faster and have additional instructions added as new models are introduced. Because PLCs are microprocessor based, they can be made to perform tasks that a computer can do. In addition to their control functions, PLCs can be networked to do supervisory control and data acquisition (SCADA).

Many electronic components found in processors and other types of PLC modules are sensitive to *electrostatic* voltages that can degrade their performance or damage them. The following static control procedures should be followed when handling and working with static-sensitive devices and modules:

- Ground yourself by touching a conductive surface before handling static-sensitive components.
- Wear a wrist strap that provides a path to bleed off any charge that may build up during work.
- Be careful not to touch the backplane connector or connector pins of the PLC system (always handle the circuit cards by the edge if possible).
- Be careful not to touch other circuit components in a module when you configure or replace its internal components.
- When not in use, store module in its static-shield bag.
- If available, use a static-safe work station.

2.7 Memory Design

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. Data are stored in memory locations by a process called *writing*. Data are retrieved from memory by what is referred to as *reading*.

The complexity of the program determines the amount of memory required. Memory elements store individual pieces of information called *bits* (for *binary digits*). The amount of memory capacity is specified in increments of

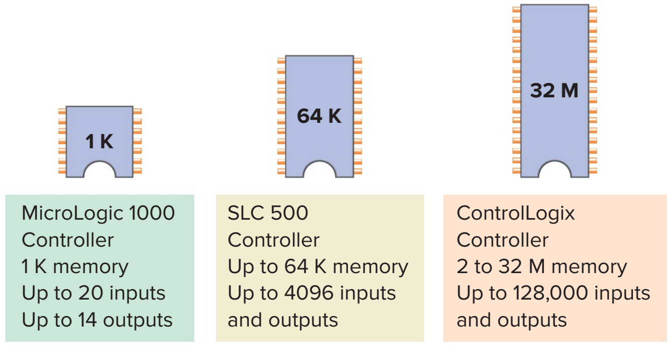


Figure 2-41 Typical PLC memory sizes.

1000 or in "K" increments, where 1 K is 1024 bytes of memory storage (a byte is 8 bits).

The program is stored in the memory as 1s and 0s, which are typically assembled in the form of 16-bit words. Memory sizes are commonly expressed in thousands of words that can be stored in the system; thus 2 K is a memory of 2000 words, and 64 K is a memory of 64,000 words. The memory size varies from as small as 1 K for small systems to 32 MB for very large systems (Figure 2-41). Memory capacity is an important prerequisite for determining whether a particular processor will handle the requirements of the specific application.

Memory *location* refers to an address in the CPU's memory where a binary word can be stored. A word usually consists of 16 bits. Each binary piece of data is a bit and eight bits make up one byte (Figure 2-42). Memory

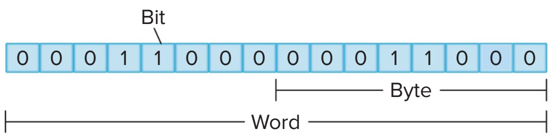


Figure 2-42 Memory bit, byte, and word.

utilization refers to the number of memory locations required to store each type of instruction. A rule of thumb for memory locations is one location per coil or contact. One K of memory would then allow a program containing 1000 coils and contacts to be stored in memory.

The memory of a PLC may be broken into sections that have specific functions. 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 2-43). These terms simply refer to a location where the status of an input or output device is stored. 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.

PLCs execute memory-checking routines to be sure that the PLC memory has not been corrupted. This memory checking is undertaken for safety reasons. It helps ensure that the PLC will not execute if memory is corrupted.

2.8 Memory Types

Memory can be placed into two general categories: volatile and nonvolatile. Volatile memory will lose its stored information if all operating power is lost or removed. Volatile memory is easily altered and is quite suitable for most applications when supported by battery backup.

Nonvolatile memory has the ability to retain stored information when power is removed accidentally or intentionally. As the name implies, programmable logic controllers have programmable memory that allows users

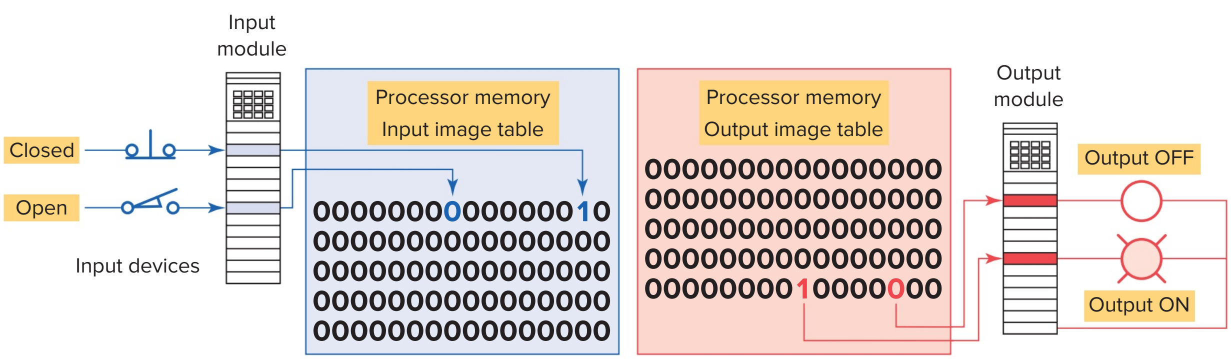


Figure 2-43 Input and output tables.

to develop and modify control programs. This memory is made nonvolatile so that if power is lost, the PLC holds its programming.

Read Only Memory (ROM) stores programs, and data cannot be changed after the memory chip has been manufactured. ROM is normally used to store the programs and data that define the capabilities of the PLC. ROM memory is nonvolatile, meaning that its contents will not be lost if power is lost. ROM is used by the PLC for the operating system. The operating system is burned into ROM by the PLC manufacturer and controls the system software that the user uses to program the PLC. When Allen Bradley burns the operating system into memory it is called PROM (programmable read-only memory).

Random Access Memory (RAM), sometimes referred to as *read-write (R/W) memory,* is designed so that information can be written into or read from the memory. RAM is used as a temporary storage area of data that may need to be quickly changed. RAM is volatile, meaning that the data stored in RAM will be lost if power is lost. A battery backup is required to avoid losing data in the event of a power loss (Figure 2-44). Most PLCs use CMOS-RAM technology for user memory. CMOS-RAM chips have very low current draw and can maintain memory with a lithium battery for an extended time, two to five years in many cases. Some processors have a capacitor that provides at least 30 minutes of battery backup when the battery is disconnected and power is OFF.

Erasable Programmable Read-Only Memory (EPROM) provides some level of security against unauthorized or unwanted changes in a program. EPROMs are designed so that data stored in them can be read, but not easily altered without special equipment. For example, UV EPROMs (ultraviolet erasable programmable read-only memory) can only be erased with an ultraviolet light. EPROM memory is used to back up, store, or transfer PLC programs.

Electrically erasable programmable read-only memory (EEPROM) is a nonvolatile memory that offers the same programming flexibility as does RAM. The EEPROM can be electrically overwritten with new data instead of being erased with ultraviolet light. Because the EEPROM is nonvolatile memory, it does not require battery backup. It provides permanent storage of the program and can be changed easily using standard programming devices. Typically, an EEPROM memory module is used to store, back up, or transfer PLC programs (Figure 2-45).

Flash EEPROMs are similar to EEPROMs in that they can only be used for backup storage. The main difference comes in the flash memory: they are extremely fast at saving and retrieving files. In addition, they do not need to be physically removed from the processor for reprogramming; this can be done using the circuitry within the processor module in which they reside. Flash memory is also sometimes built into the processor module (Figure 2-46), where it automatically backs up parts of RAM. If power fails while a PLC with flash memory is running, the PLC will resume running without having lost any working data after power is restored.

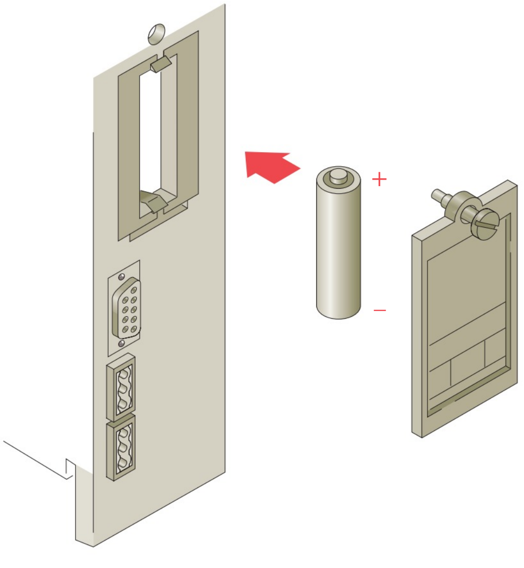


Figure 2-44 Battery used to back up processor RAM.

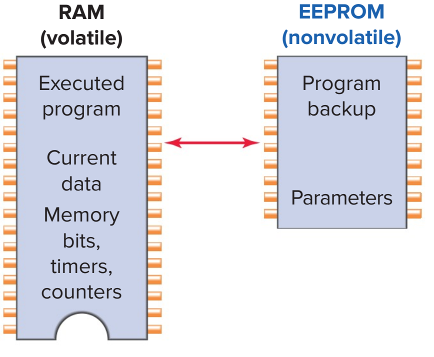


Figure 2-45 EEPROM memory module is used to store, back up, or transfer PLC programs.

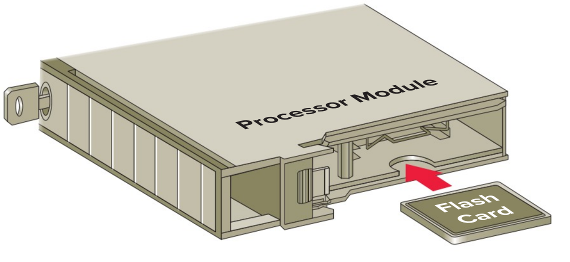


Figure 2-46 Flash memory card installed in a socket on the processor.

2.9 Programming Terminal Devices

A programming terminal device is needed to enter, modify, and troubleshoot the PLC program. PLC manufacturers use various types of programming devices. The simplest type is the hand-held type programmer shown in Figure 2-47. This proprietary programming device has a connecting cable so that it can be plugged into a PLC's programming port. Certain controllers use a plug-in panel rather than a hand-held device.

Hand-held programmers are compact, inexpensive, and easy to use. These units contain multifunction keys and a liquid-crystal display (LCD) or light-emitting diode (LED) window. There are usually keys for instruction entering and editing, and navigation keys for moving around the program. Hand-held programmers have limited display capabilities. Some units will display only the last instruction that has been programmed, whereas other units will display from two to four rungs of ladder logic. So-called intelligent hand-held programmers are designed to support a certain family of PLCs from a specific manufacturer.

The most popular method of PLC programming is to use a personal computer (PC) in conjunction with the manufacturer's programming software (Figure 2-48). Typical capabilities of the programming software include online and offline program editing, online program monitoring, program documentation, diagnosing malfunctions in the PLC, and troubleshooting the controlled system. Hard-copy reports generated in the software can be printed on the computer's printer. Most software packages will not allow you to develop programs on another manufacturer's PLC. In some cases, a single manufacturer will have multiple PLC families, each requiring its own software to program.

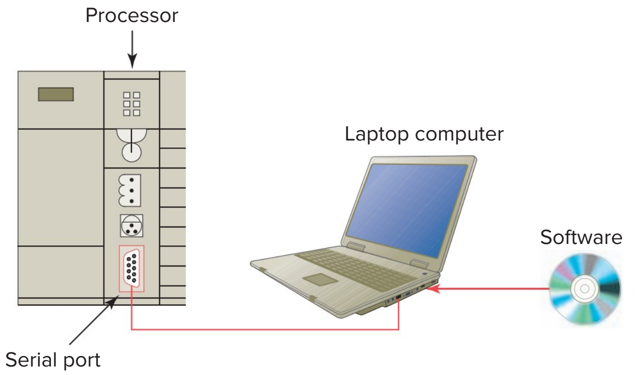


Figure 2-48 Personal computer used as the programming device.

2.10 Recording and Retrieving Data

Printers are used to provide hard-copy printouts of the processor's memory in ladder program format. Lengthy ladder programs cannot be shown completely on a screen. Typically, a screen shows a maximum of five rungs at a time. A printout can show programs of any length and analyze the complete program.

The PLC can have only one program in memory at a time. To change the program in the PLC, it is necessary either to enter a new program directly from the keyboard or to download one from the computer hard drive. Some CPUs support the use of a memory cartridge that provides portable EEPROM storage for the user program (Figure 2-49). The cartridge can be used to copy a program from one PLC to another similar type PLC.

2.11 Human Machine Interfaces (HMIs)

In the past, the typical user interface to a control system consisted of a panel with switches, pushbuttons, pilot lights, gauges, analog meters, and the like. With the advent of

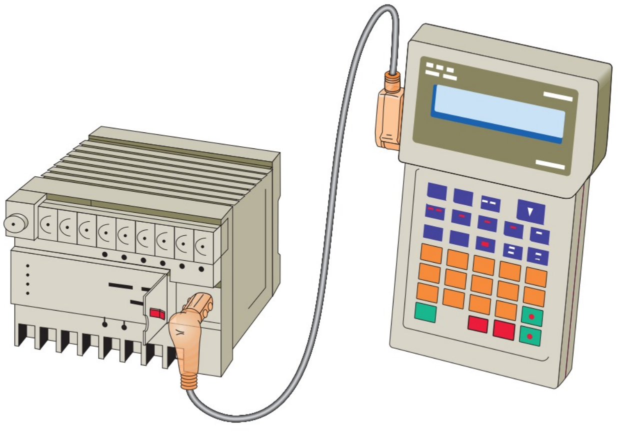


Figure 2-47 Hand-held programming terminal.

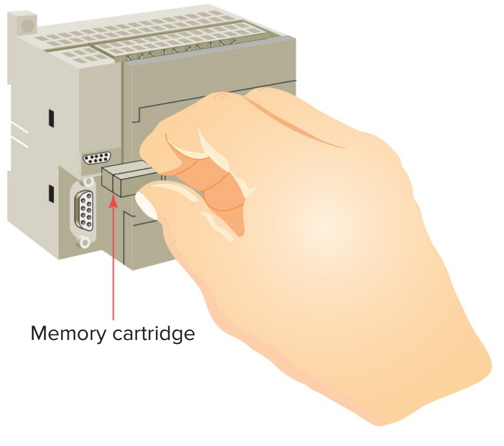


Figure 2-49 Memory cartridge provides portable storage for user program.

Figure 2-50 Human Machine Interface (HMI).
Source: Courtesy of Nercon.

digital control systems, larger hard-wired panels have been replaced by a computer screen with process graphics and operator commands entered via a keyboard (Figure 2-50).

Human machine interfaces give the ability to the operator and to management to view the operation in real time. Through personal computer–based setup software, you can configure display screens to:

- Replace hardwired pushbuttons and pilot lights with realistic-looking icons. The machine operator need only touch the display panel to activate the pushbuttons.
- Show operations in graphic format for easier viewing.
- Allow the operator to change timer and counter presets by touching the numeric keypad graphic on the touch screen.
- Show alarms, complete with time of occurrence and location.
- Display variables as they change over time.

The Allen-Bradley Pico GFX-70 controller, shown in Figure 2-51, serves as a controller with HMI capabilities. This device consists of three modular parts: an HMI, processor/power supply, and I/O modules.

The display/keypad can be used as an operator interface or can be linked to control operations to provide real-time feedback. It has the ability to show text, date and time, as well as custom messages and bitmap graphics,

Figure 2-51 Allen-Bradley Pico GFX-70 controller.
Source: Image Courtesy of Rockwell Automation, Inc.

allowing operators to acknowledge fault messages, enter values, and initiate actions. Users can create both the control program and HMI functionality using a personal computer with PicoSoft Pro software installed or the controller's on-board display buttons.

Human Machine Interfaces (HMIs), are also referred to as User Interface, Operator Panel, or Terminal and provide a means of *controlling*, *monitoring, managing*, and/or visualizing device processes. They can be located on the machine or in centralized control rooms. The general structure of an HMI package is shown in Figure 2-52. The tag database variables are programmed to interact with the graphic screen objects and communicate with the PLC through the I/O server.

The design of the HMI application plays a critical role in determining the operator's ability to effectively manage the operation, particularly in response to abnormal situations. The major tasks in the development of an HMI application are:

- *Set up the communication with the PLC*. This involves configuring all necessary software and hardware components.

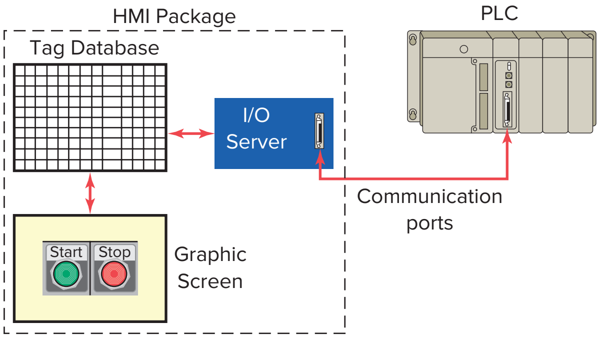


Figure 2-52 General structure of a HMI package.

- *Create the tag database*. Most HMI packages provide a way to import tags from the PLC programming software.
- *Insert the graphical objects on the screen*. Graphics are drawn or imported from a library of common objects.
- *Animate the objects*. There are two basic types of animation: user input and display. User input types allow an operator to change tag values. A display animation allows a value to be displayed and also allows an object to change shape, position, and color.

Many different types of HMI hardware and software features are available. These include:

HMI MONITOR AND ENCLOSURE

HMI operator panels typically contain monochrome or 256 color display screens. These systems often communicate directly with the PLC to read or write memory locations.

- A monochrome monitor uses one color for the background and another to display text or images on the screen.
- Color displays enable clearer process representation and in general brighten up their systems. The color convention for status and alarms should follow the same convention as their hardwired equivalents, namely:
  - *Red*—for alarm, danger, and stop
  - *Yellow*—for caution and risk of danger
  - *Green*—for ready, running, and safe condition
- Screen resolution is expressed as width × height, with the units in pixels.
- Screen memory is expressed in Megabytes (MB).
- The environmental certification refers to the type of electrical enclosure used to protect their contents from troublesome operating conditions such as dust, liquids, and extreme variations in temperature (Figure 2-53).
- The screen may or may not be touch-sensitive. The touch-sensitive screen allows for more devices and data to be displayed in a smaller area. Detailed information about an object can be accessed by touching the object.

ALARMS

Alarms are messages which indicate that a fault condition is present (Figure 2-54). An alarm summary can present a complete list of timestamped active alarms. Typically an alarm can exist in the following states:

Figure 2-53 HMI installed in an industrial environment.
Source: Photo Courtesy PC Enclosures, **http://www.pcenclosures.net.**

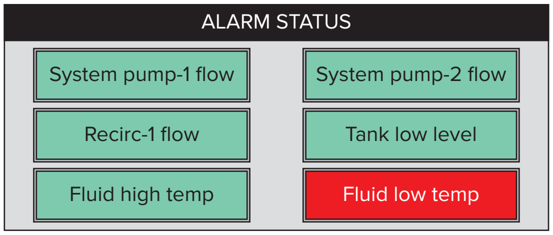


Figure 2-54 Typical alarm status screen.

- *Inactive*—The condition being monitored does not have any faults present, and there is no associated alarm message waiting to be acknowledged.
- *Active*—A fault condition is present, and the alarm message has not been acknowledged by the operator.
- *Acknowledged*—The fault condition is present, and the operator has acknowledged the alarm message.
- *OK* - The fault condition is no longer present, but the operator has not acknowledged the alarm message yet.

EVENT HISTORY

An event history presents a time-stamped list of all significant events that have occurred in the process. Many problems within the plant or equipment may occur when no one is monitoring the system, and intermittent problems may be difficult to diagnose without a history of previous issues.

TREND

Values of important process variables, such as flow, temperature, and production rate, over a period of time are shown by this type of display. This type of display provides the ability to chart the progress of the process in real time, providing the same function as a strip chart recorder. For example, suppose you are monitoring pressure of a Pounds per Square Inch Gauge (psig) as shown in Figure 2-55. According to the table, you can see that it's OK right now, but that's all you know. This trend shows the pressure oscillating around a known good level. We may want to check on the cause of oscillation, but there appears to be no immediate problem.

Current Pressure	Alarm Level	Shutdown Level
235.2 psig	250 psig	300 psig

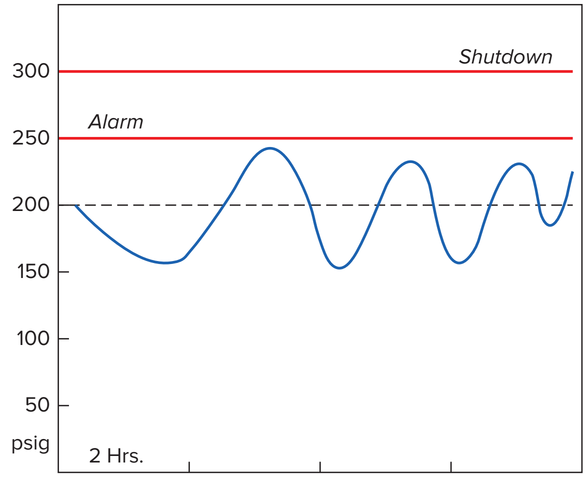


Figure 2-55 Trend monitoring of a pressure gauge.

GRAPHICS LIBRARY

The graphics library contained within an HMI development package provides buttons, lights, switches, sliders, meters, fills, and other graphic objects (Figure 2-56). It saves design time by providing graphics and faceplates for numerous industrial control devices that would otherwise have to be created manually. Librarian applications may include easy-to-use features for resizing, changing color scheme, and orientation of objects, as well as building your own graphics into the library.

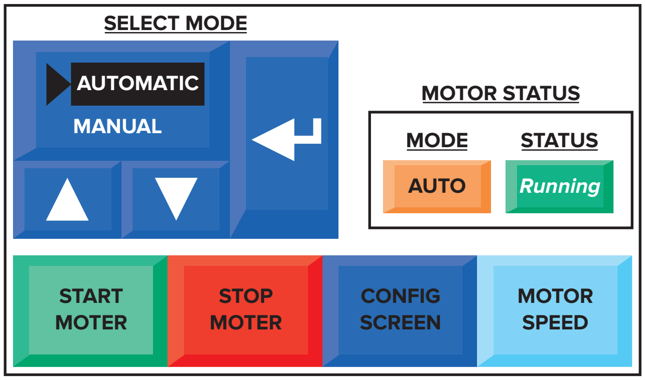


Figure 2-56 Typical motor control graphics.

CHAPTER 2 REVIEW QUESTIONS

1. What is the function of a PLC input interface module?
2. What is the function of a PLC output interface module?
3. With reference to a PLC rack:
   a. What is a *remote rack?*
   b. Why are remote racks used?
4. How does the processor identify the location of a specific input or output device?
5. List the three basic elements of rack/slot-based addressing.
6. Compare bit level and word level addressing.
7. In what way does tag-based addressing differ from rack/slot-based addressing?
8. What do PC-based control systems use to interface with field devices?
9. What type of I/O modules have both inputs and outputs connected to them?
10. In addition to field devices, what other connections are made to a PLC module?
11. Most PLC modules use plug-in wiring terminal strips. Why?
12. What are the advantage and the disadvantage of using high-density modules?
13. With reference to PLC discrete input modules:
    a. What types of field input devices are suitable for use with them?
    b. List three examples of discrete input devices.
14. With reference to PLC discrete output modules:
    a. What types of field output devices are suitable for use with them?
    b. List three examples of discrete output devices.
15. Explain the function of the backplane of a PLC rack.
16. What is the function of the optical isolator circuit used in discrete I/O module circuits?
17. Name the two distinct sections of an I/O module.
18. List four tasks performed by a discrete input module.
19. What electronic element can be used as the switching device for a 120 VAC discrete output interface module?
20. With reference to discrete output module current ratings:
    a. What is the maximum current rating for a typical 120 VAC output module?
    b. Explain one method of handling outputs with larger current requirements.
21. What electronic element can be used as the switching device for DC discrete output modules?
22. A discrete relay type output module can be used to switch either AC or DC load devices. Why?
23. With reference to sourcing and sinking I/O modules:
    a. What current relationship are the terms *sourcing* and *sinking* used to describe?
    b. If an I/O module is specified as a current-sinking type, then which type of field device (sinking or sourcing) it is electrically compatible with?
24. Compare discrete and analog I/O modules with respect to the type of input or output devices with which they can be used.
25. Explain the function of the analog-to-digital (A/D) converter circuit used in analog input modules.
26. Explain the function of the digital-to-analog (D/A) converter circuit used in analog output modules.
27. Name the two general sensing classifications for analog input modules.
28. List five common physical quantities measured by a PLC analog input module.
29. What type of cable is used when connecting a thermocouple to a voltage sensing analog input module? Why?
30. Explain the difference between a unipolar and bipolar analog input module.
31. The resolution of an analog input channel is specified as 0.3 mV. What does this tell you?
32. In what two ways can the loop power for current sensing input modules be supplied?
33. List three field devices that are commonly controlled by a PLC analog output module.
34. State one application for each of the following special I/O modules:
    a. High-speed counter module
    b. Thumbwheel module
    c. TTL module
    d. Encoder-counter module
    e. BASIC or ASCII module
    f. Stepper-motor module
    g. BCD-output module

35. List one application for each of the following intelligent I/O modules:
    a. PID module
    b. Motion and position control module
    c. Communication module
36. Write a short explanation for each of the following discrete I/O module specifications:
    a. Nominal input voltage
    b. Input threshold voltages
    c. Nominal current per input
    d. Ambient temperature rating
    e. Input ON/OFF delay
    f. Output voltage
    g. Output current
    h. Inrush current
    i. Short circuit protection
    j. Leakage current
    k. Electrical isolation
    l. Points per module
    m. Backplane current draw
37. Write a short explanation for each of the following analog I/O module specifications:
    a. Channels per module
    b. Input current/voltage range(s)
    c. Output current/voltage range(s)
    d. Input protection
    e. Resolution
    f. Input impedance and capacitance
    g. Common-mode rejection
38. Compare the function of the CPU and memory sections of a PLC processor.
39. With reference to the PLC chassis power supply:
    a. What conversion of power takes place within the power supply circuit?
    b. Explain the term *hold-up time* as it applies to the power supply.
40. Explain the purpose of a redundant PLC processor.
41. Describe three typical modes of operation that can be selected by the keyswitch of a processor.
42. State five other functions, in addition to simple logic processing, that PLC processors are capable of performing.
43. List five important procedures to follow when handling static-sensitive PLC components.
44. Define each of the following terms as they apply to the memory element of a PLC:
    a. writing
    b. reading
    c. bits
    d. location
    e. utilization
45. With reference to the I/O image tables:
    a. What information is stored in PLC input and output tables?
    b. What is the input status of a closed switch stored as?
    c. What is the input status of an open switch stored as?
    d. What is the status of an output that is ON stored as?
    e. What is the status of an output that is OFF stored as?
46. Why do PLCs execute memory-checking routines?
47. Compare the memory storage characteristics of volatile and nonvolatile memory elements.
48. What information is normally stored in the ROM memory of a PLC?
49. What information is normally stored in the RAM memory of a PLC?
50. What information is normally stored in an EEPROM memory module?
51. What are the advantages of a processor that utilizes a flash memory card?
52. List three functions of a PLC programming terminal device.
53. Give one advantage and one limitation to the use of hand-held programming devices.
54. What is required for a personal computer to be used as a PLC programming terminal?
55. List four important capabilities of PLC programming software.
56. How many programs can a PLC have stored in memory at any one time?
57. Outline four functions that an HMI interface screen can be configured to perform.
58. List the four major tasks in the development of an HMI application.
59. What information does an HMI trend display convey?
60. Define the term scaling as it applies to PLC inputs and outputs.
61. What is the function of a transducer?
62. In a tag based PLC memory structure, what is the function of a base tag and an alias tag?

CHAPTER 2 PROBLEMS

1. A discrete 120 VAC output module is to be used to control a 230 VDC solenoid valve. Draw a diagram showing how this could be accomplished using an interposing relay.
2. Assume a thermocouple, which supplies the input to an analog input module, generates a linear voltage of from 20 to 50 mV when the temperature changes from 750 to 1250°F. How much voltage will be generated when the temperature of the thermocouple is at 1000°F?
3. With reference to I/O module specifications:
   a. If the ON-delay time of a given discrete input module is specified as 12 ms, how much is this expressed in seconds?
   b. If the output leakage current of a discrete output module is specified as 950 µA, how much is this expressed in amperes?
   c. If the ambient temperature rating for an I/O module is specified as 60°C, how much is this expressed in degrees Fahrenheit?
4. Create a five-digit code using the SLC 500 rack/slot-based addressing format for each of the following:
   a. A pushbutton connected to terminal 5 of module group 2 located on rack 1.
   b. A lamp connected to terminal 3 of module group 0 located on rack 2.
5. Assume the triac of an AC discrete output module fails in the shorted state. How would this affect the device connected to this output?
6. A personal computer is to be used to program several different PLCs from different manufacturers. What would be required?