



➤ Chapter 2

➤ PLC Hardware Components



❑ Chapter Objectives

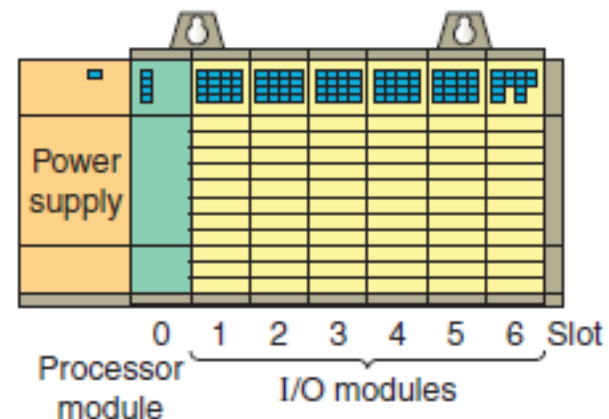
✓ *After completing this chapter, you will be able to:*

- 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



❑ 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.
- 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





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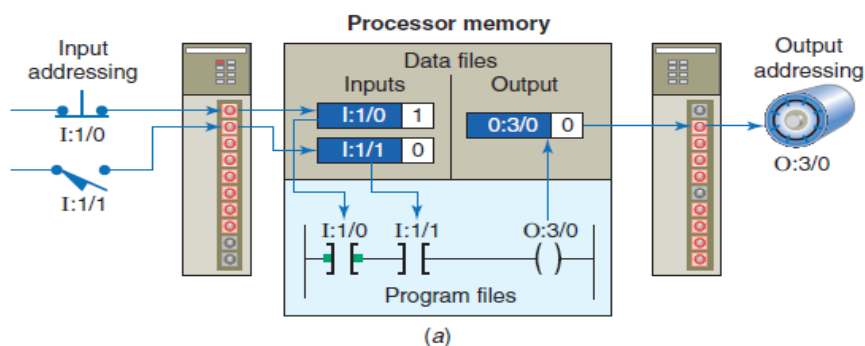
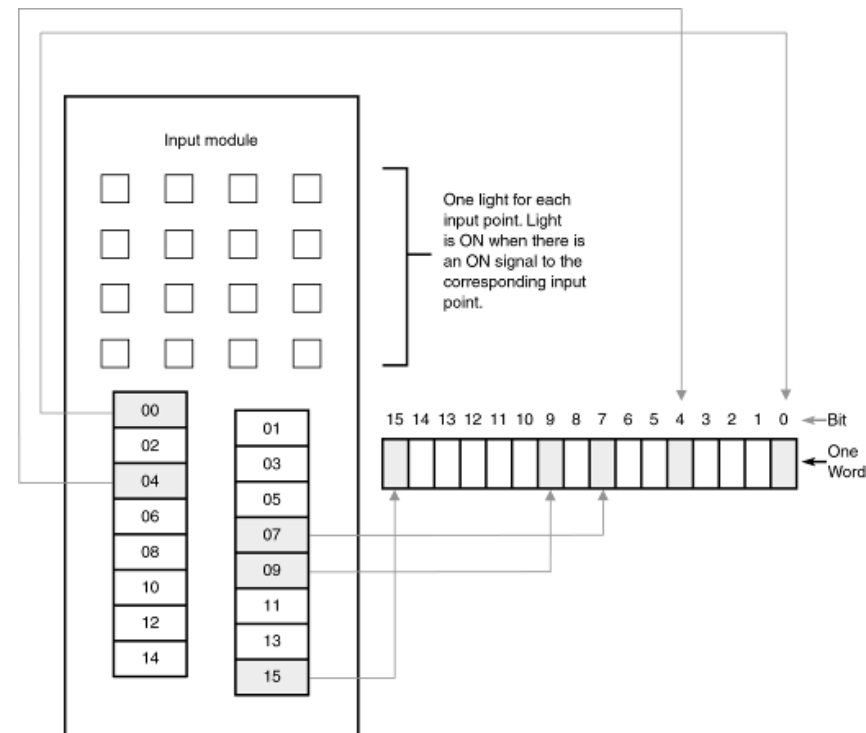
Programmable Logic Controller



❑ The I/O Section

➤ each input and output pin in slot of the PLC will have an address

Input or Output	Chassis slot	Screw terminal	Address
Input	1	4	1:1/4
Output	1	13	0:2/13
Input	3	2	1:3/2
Input	4	4	1:4/4
Output	5	9	1:5/9
Input	6	0	1:6/0



The address is used by the processor to identify where the device is located to monitor or control it.



❑ The I/O Section

➤ 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,



❑ The I/O Section

➤ Discrete I/O Modules

Color	Type of I/O
Red	AC inputs/outputs
Blue	DC inputs/outputs
Orange	Relay outputs

Table 2-1 Common Ratings for Discrete I/O Interface Modules

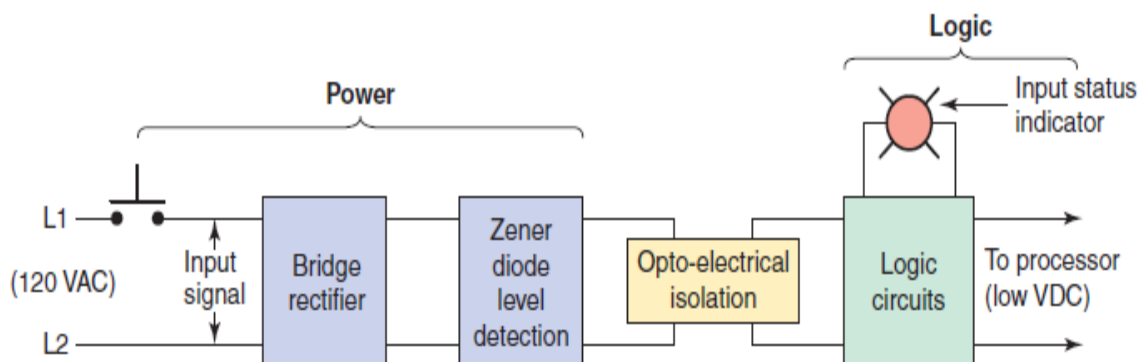
Input Interfaces	Output Interfaces
12 V AC/DC /24 V AC/DC	12–48 V AC
48 V AC/DC	120 V AC
120 V AC/DC	230 V AC
230 V AC/DC	120 V DC
5 V DC (TTL level)	230 V DC
	5 V DC (TTL level)
	24 V DC



❑ The I/O Section

➤ Discrete I/O Modules

- Figure 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.

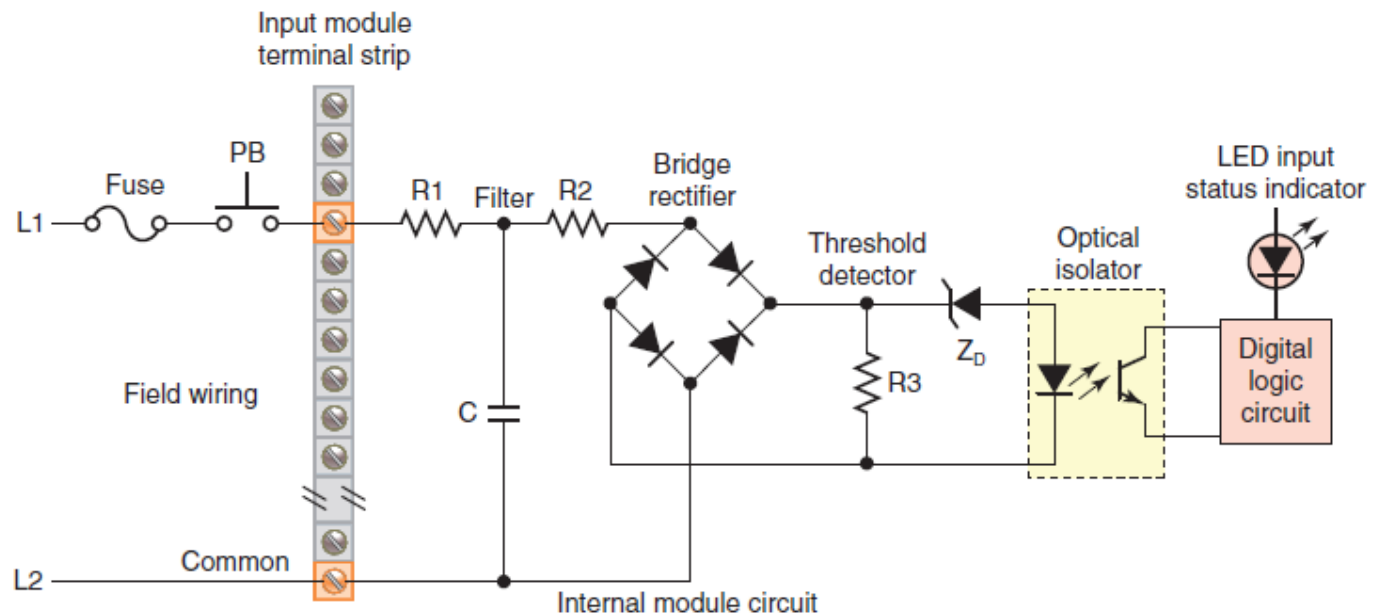




❑ The I/O Section

➤ Discrete I/O Modules

- 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.

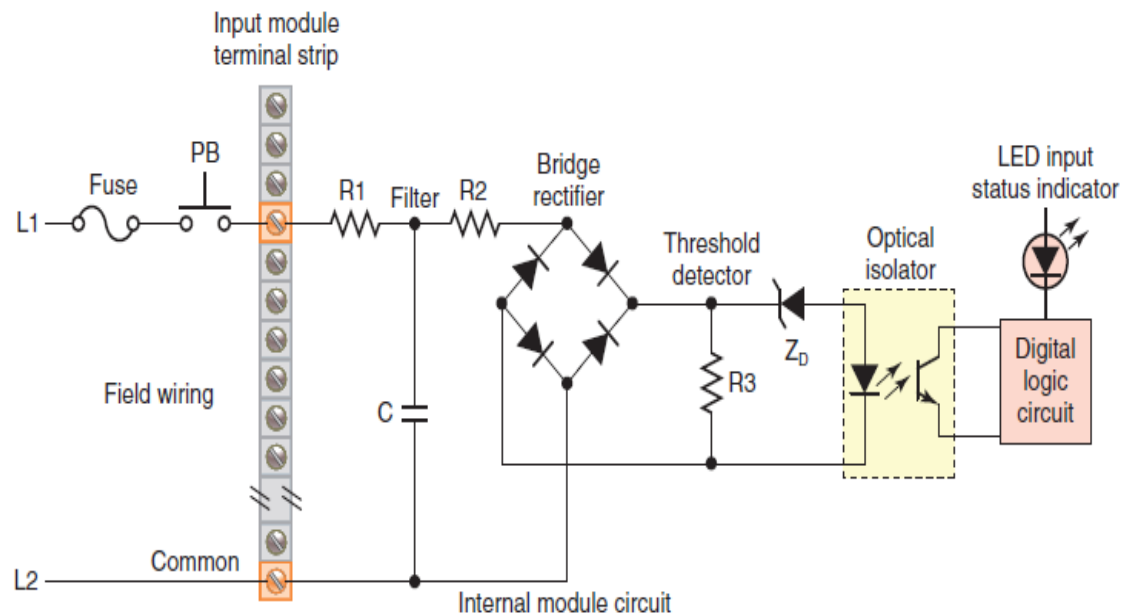




❑ The I/O Section

➤ Discrete I/O Modules

- 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.

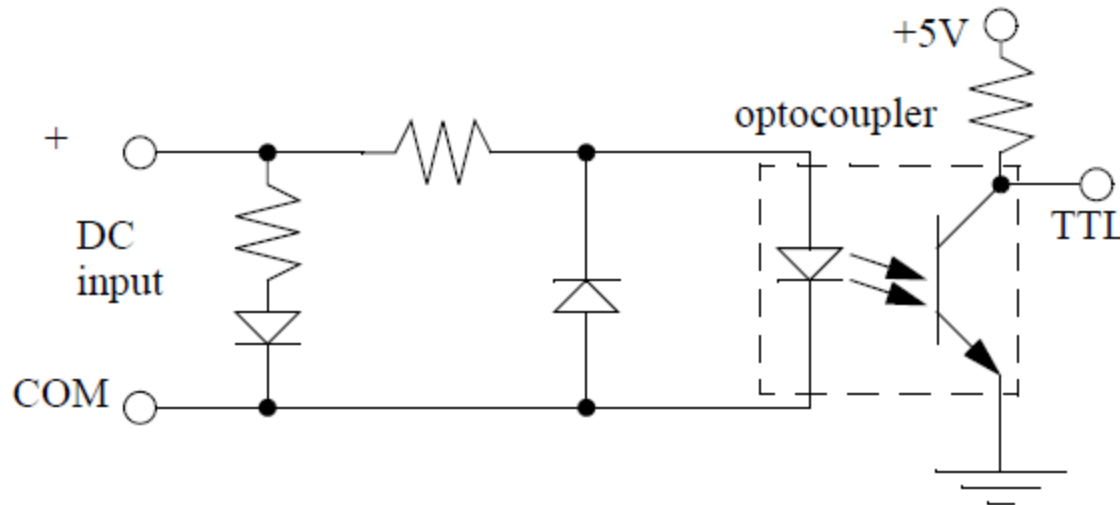




❑ The I/O Section

➤ Discrete I/O Modules

- The input signal for the PLC can be either AC or DC
- If the input signal is AC then the circuit that convert this AC signal into DC was shown in previous slide
- If the input signal is DC then the circuit below will be used to convert the signal into 5 volt signal





❑ The I/O Section

➤ Discrete I/O Modules

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

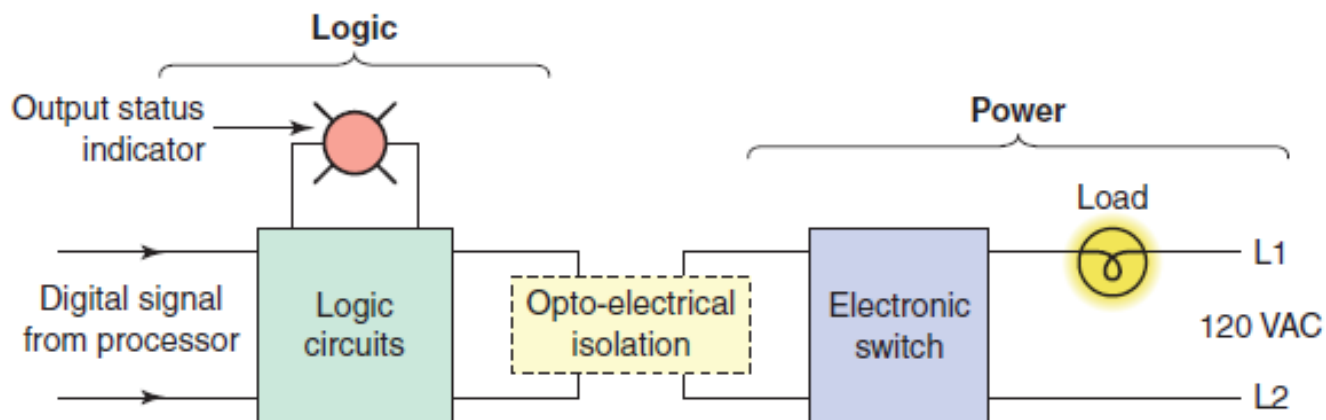
- Sense when a signal is received from a field device.
- Convert the input signal to the correct voltage level for the particular PLC.
- Isolate the PLC from fluctuations in the input signal's voltage or current.
- Send a signal to the processor indicating which sensor originated the signal.



❑ The I/O Section

➤ Discrete I/O Modules

- Figure 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.





❑ The I/O Section

➤ Discrete I/O Modules

➤ A simplified diagram for a single output of a discrete AC output module is shown in Figure .

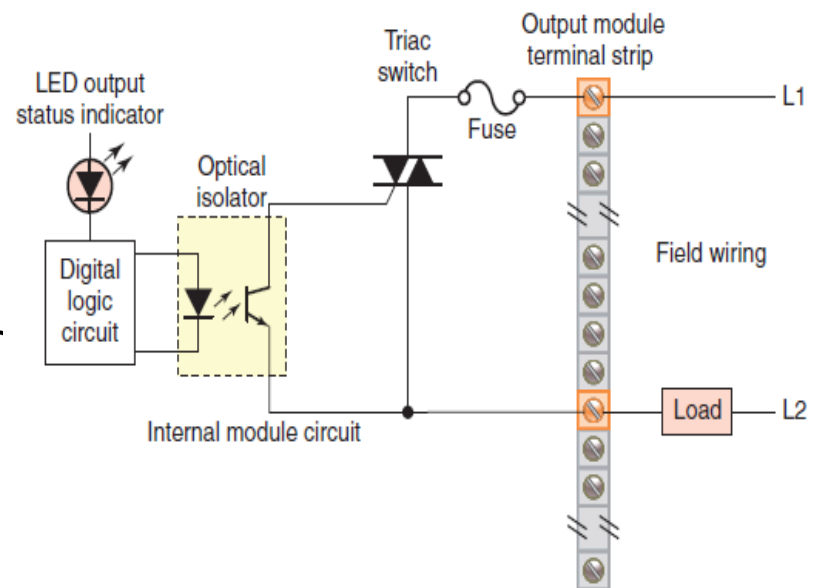
➤ The operation of the circuit can be summarized as follows:

- 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 flow to the output load.



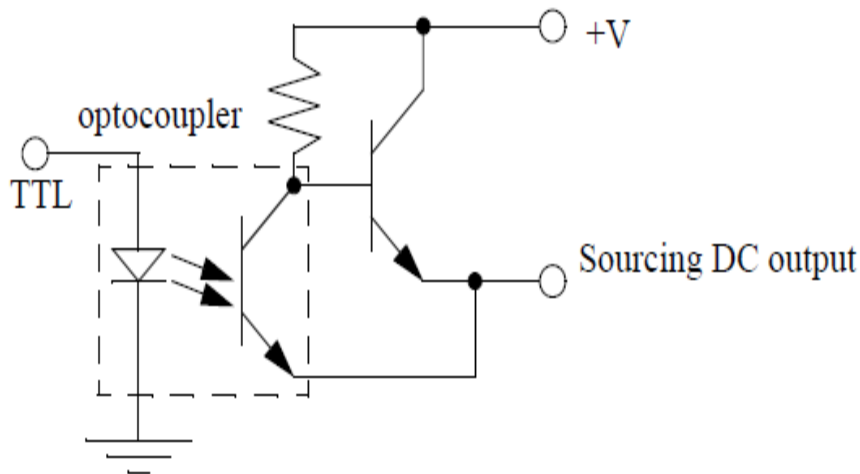


❑ The I/O Section

➤ Discrete I/O Modules

- PLC outputs must convert the 5Vdc logic levels on the PLC data bus to external voltage levels. This can be done with circuits similar to those shown below.

Transistor (DC output)

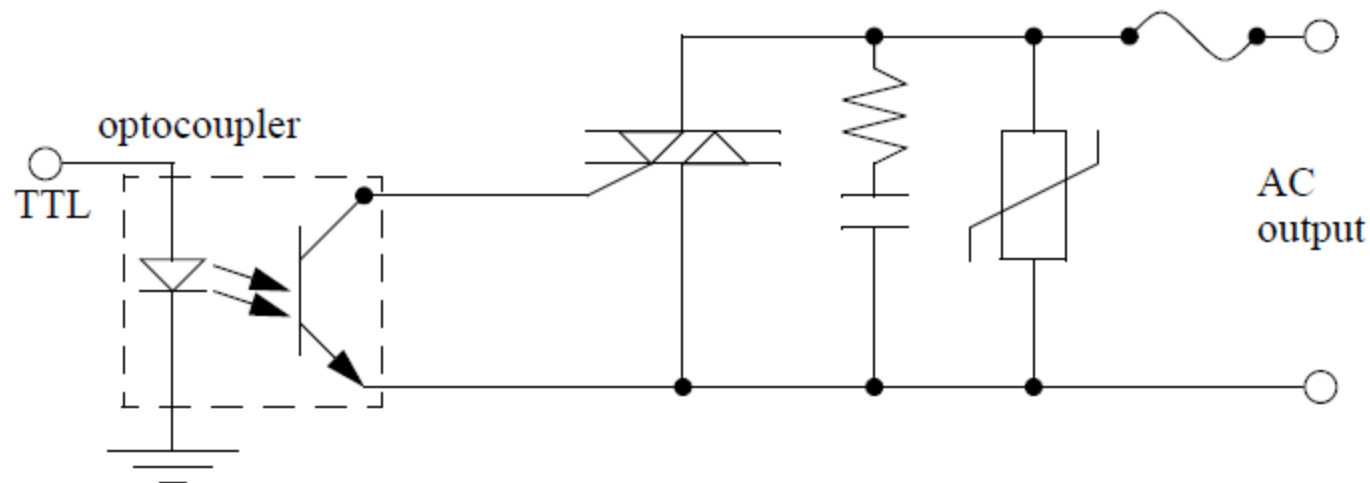




❑ The I/O Section

➤ Discrete I/O Modules

Traic (AC output)

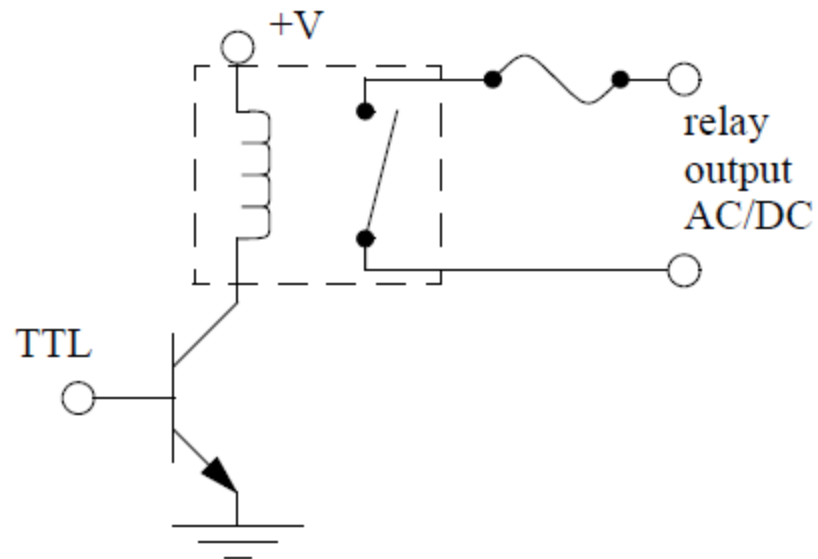




❑ The I/O Section

➤ Discrete I/O Modules

Relay (AC and DC output)





❑ The I/O Section

➤ Discrete I/O Modules

- 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.



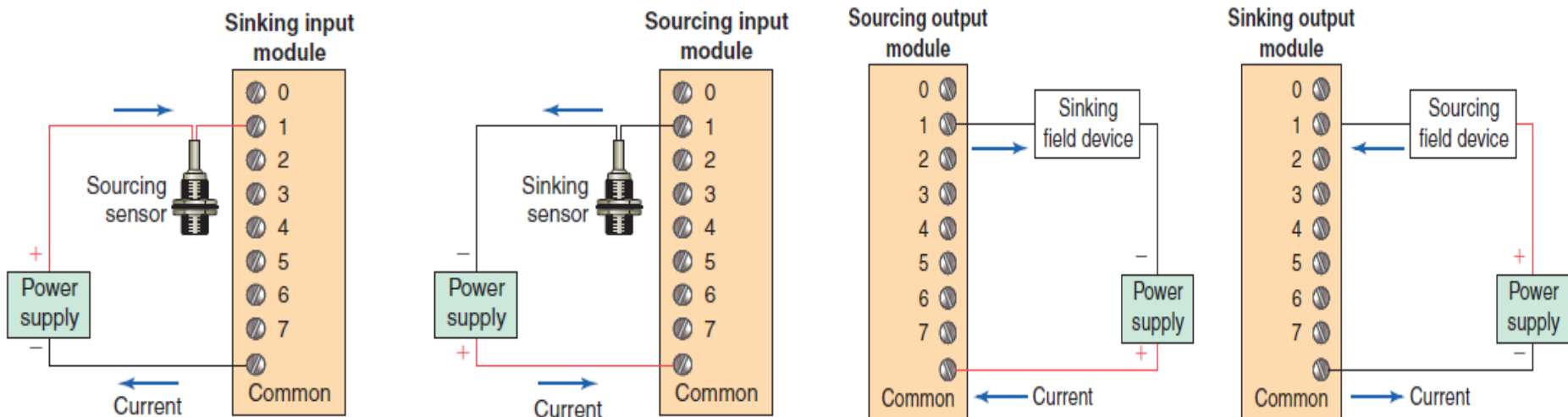
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❑ The I/O Section

➤ Discrete I/O Modules

- In general, *sinking* (NPN) and *sourcing* (PNP) are terms used to describe a current signal flow relationship between field input and output devices in a control system and their power supply.
- Figure illustrates the current flow relationship between sinking and sourcing inputs to a DC input module.





❑ The I/O Section

➤ Discrete I/O Modules

- A major issue with outputs is mixed power sources.
- It is good practice to isolate all power supplies and keep their commons separate, but this is not always feasible.
- Some output modules, such as relays, allow each output to have its own common. Other output cards require that multiple, or all, outputs on each card share the same common.
- Each output card will be isolated from the rest, so each common will have to be connected.
- It is common for beginners to only connect the common to one card, and forget the other cards
 - then only one card seems to work!



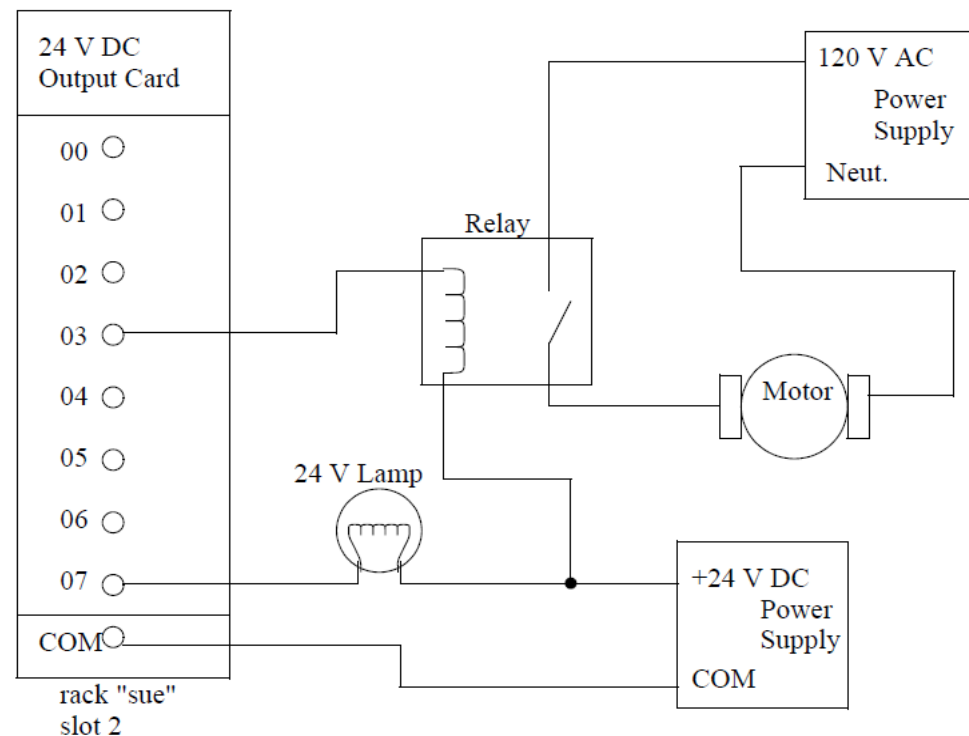
The I/O Section

➤ Discrete I/O Modules

- The output card shown in Figure 3.5 is an example of a 24Vdc output card that has a shared common.
- This type of output card would typically use transistors for the outputs.
- In this example the outputs are connected to a low current light bulb (lamp) and a relay coil.

➤ Consider the circuit through the lamp, starting at the 24Vdc supply.

➤ When the output *07 is on*, current can flow in 07 to the COM, thus completing the circuit, and allowing the light to turn on.





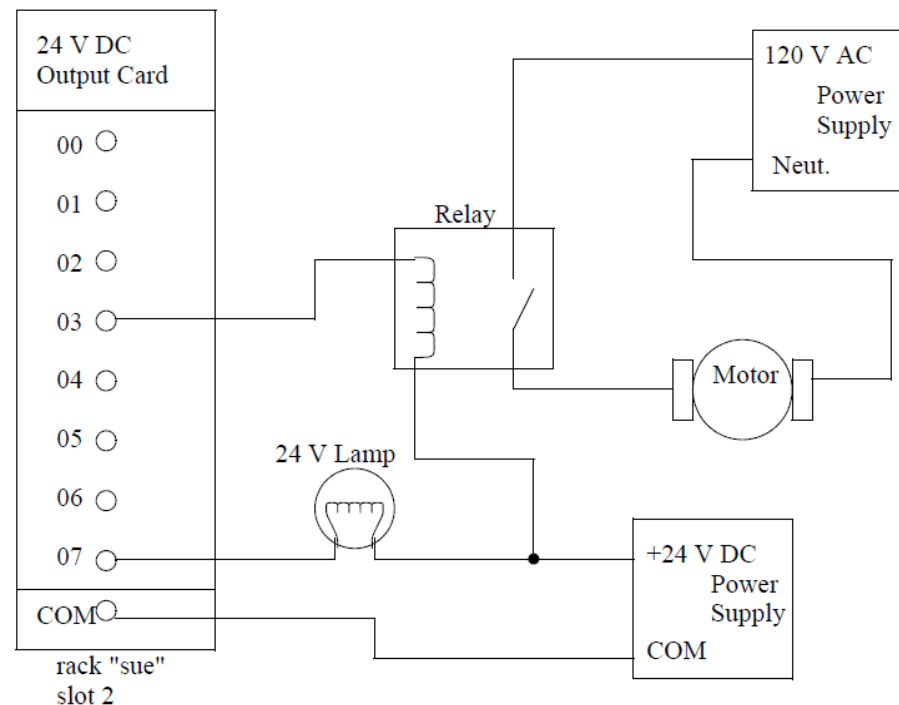
❑ The I/O Section

➤ Discrete I/O Modules

- If the output is off the current cannot flow, and the light will not turn on.
- The output 03 for the relay is connected in a similar way. When the output 03 is on, current will flow through the relay coil to close the contacts and supply 120Vac to the motor.

➤ This card could have many different voltages applied from different sources, but all the power supplies would need a single shared common.

➤ Sinking





❑ The I/O Section

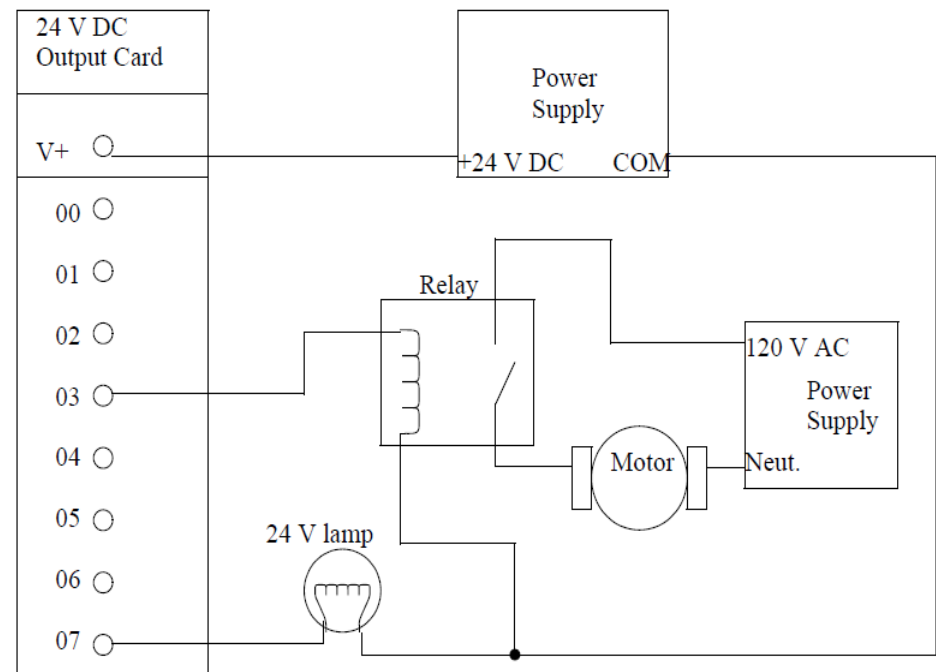
➤ Discrete I/O Modules

➤ The circuits in Figure had the sequence of power supply, then device, then PLC card, then power supply.

➤ Sourcing

➤ In this example the positive terminal Of the 24Vdc supply is connected to the output card directly.

➤ When an output is on power will be supplied to that output.

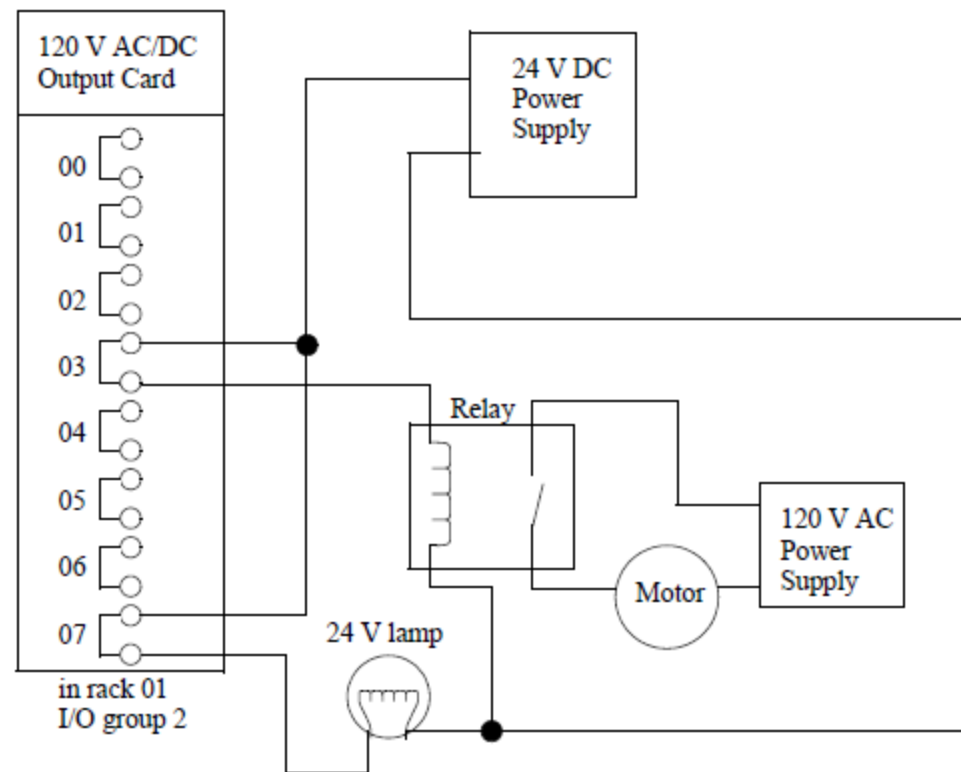




❑ The I/O Section

➤ Discrete I/O Modules

- In this example the 24Vdc supply is connected directly to both relays (note that this requires 2 connections now, whereas the previous example only required one.)
- When an output is activated the output switches on and power is delivered to the output devices.
- This layout is more similar to Figure 3.6 with the outputs supplying voltage, but the relays could also be used to connect outputs to grounds, as in Figure 3.5.
- When using relay outputs it is possible to have each output isolated from the next. A relay output card could have AC and DC outputs beside each other.





❑ The I/O Section

❖ Analogue I/O Modules

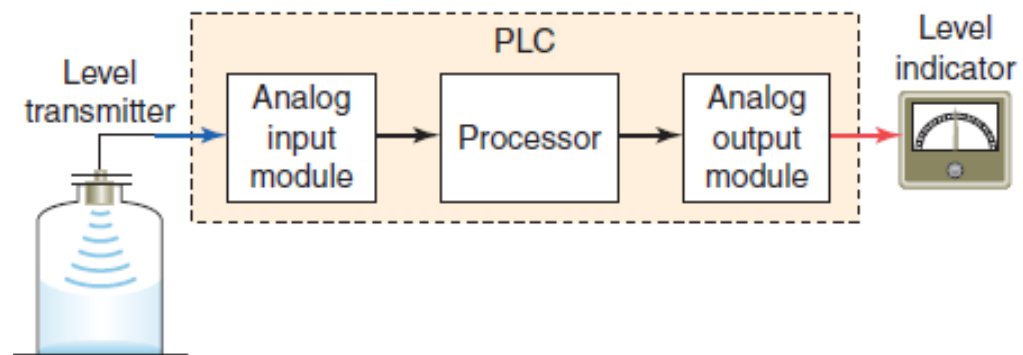
- Earlier PLCs were limited to discrete or digital I/O interfaces, which allowed only on/off-type devices to be connected.
- This limitation meant that the PLC could have only partial control of many process applications.
- Today, however, a complete range of both discrete and analogue interfaces are 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, analogue devices represent physical quantities that can have an infinite number of values.
- Typical analogue inputs and outputs vary from 0 to 20 milliamps, 4 to 20 milliamps, or 0 to 10 volts.



❑ The I/O Section

❖ Analogue I/O Modules

- Figure 2-22 illustrates how PLC analogue input and output modules are used in measuring and displaying the level of fluid in a tank.
- The analogue input interface module contains the circuitry necessary to accept an analogue voltage current signal from the level transmitter field device.
- This input is converted from an analogue to a digital value for use by the processor.
- The circuitry of the analogue output module accepts the digital value from the processor and converts it back to an analogue signal that drives the field tank level meter.





❑ The I/O Section

❖ Analogue I/O Modules

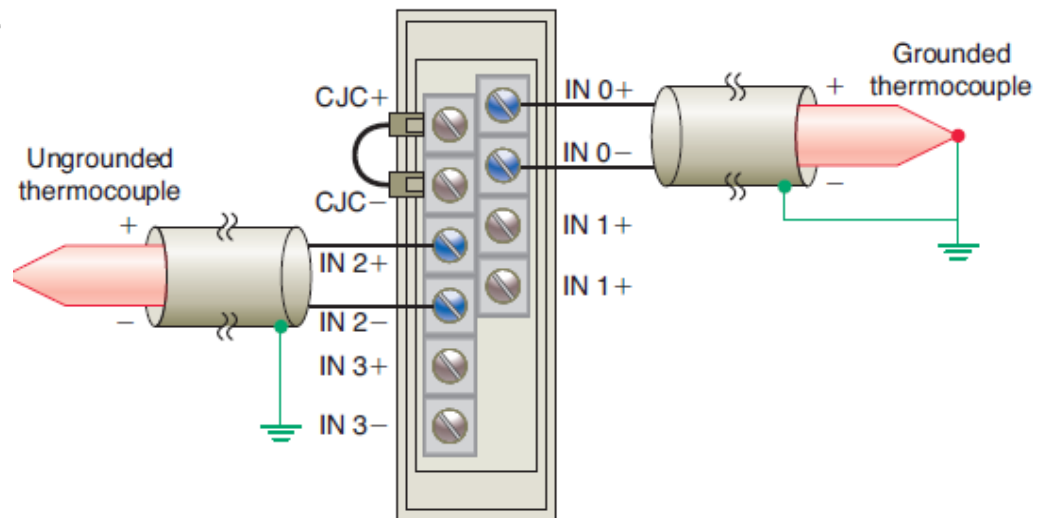
- Analogue input modules normally have multiple input channels that allow 4, 8, or 16 devices to be interface to the PLC.
- The two basic types of analogue input modules are *voltage sensing and current sensing*.
- *Analogue sensors* measure a varying physical quantity over a specific range and generate a corresponding voltage or current signal.
- Common physical quantities measured by a PLC analogue 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.



❑ The I/O Section

❖ Analogue I/O Modules

- Figure illustrates an example of a voltage sensing input analogue module used to measure temperature.
- The connection diagram applies to an Allen-Bradley Micro-Logic 4-channel analogue 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 analogue input module and then sent to the processor on command from a program instruction.

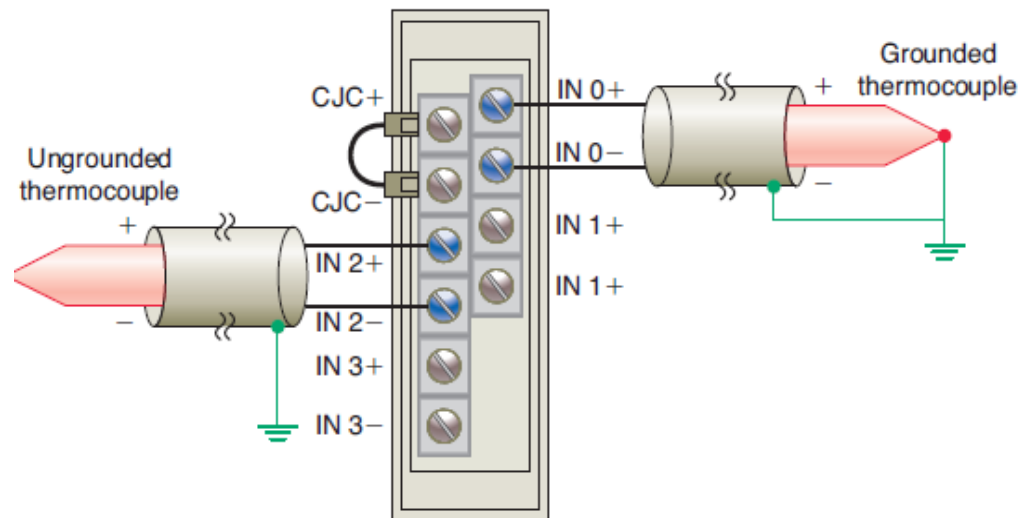




❑ The I/O Section

❖ Analogue I/O Modules

- 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 I/O Section

❖ Analogue I/O Modules

- The transition of an analogue signal to digital values is accomplished by an analogue-to-digital (A/D) converter, the main element of the analogue input module.
- Analogue voltage input modules are available in two types: unipolar and bipolar.
- *Unipolar modules can accept an input signal* that varies in the positive direction only.
- For example, if the field device outputs 0 V to 110 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 -210 V to 110 V a bipolar module would be used.
- The *resolution of an analogue* 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.



❑ The I/O Section

❖ Analogue I/O Modules

- Analogue input modules must produce a range of digital values between a maximum and minimum value to represent the analogue 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



❑ The I/O Section

❖ Analogue I/O Modules

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

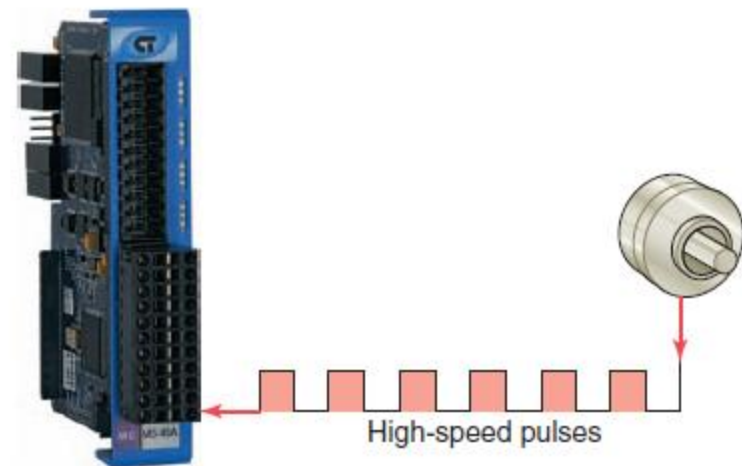


❑ The I/O Section

❖ Special I/O Modules

✓ 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) 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.





❑ The I/O Section

❖ Special I/O Modules

✓ ENCODER-COUNTER MODULE

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



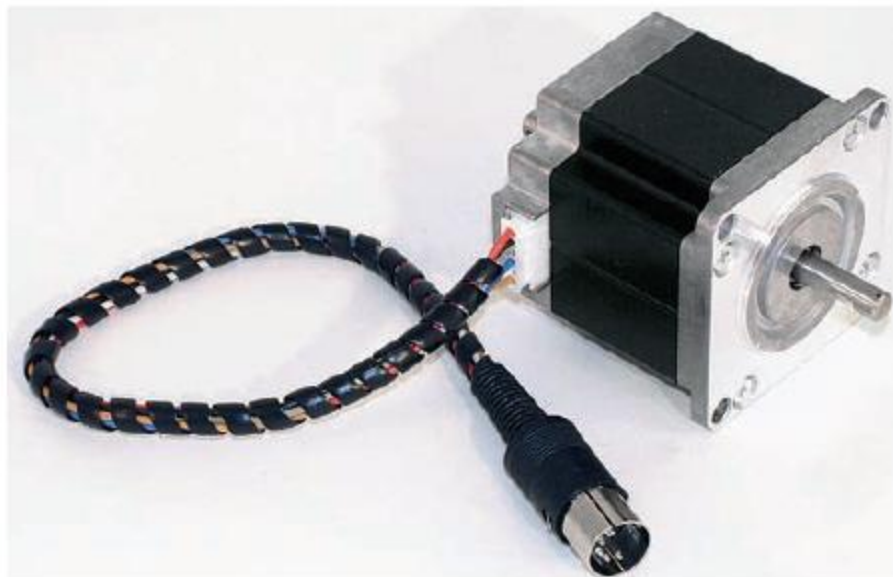


❑ The I/O Section

❖ Special I/O Modules

✓ STEPPER-MOTOR MODULE

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





❑ The I/O Section

❖ Discrete I/O Specifications

✓ NOMINAL INPUT VOLTAGE

- This discrete input module voltage value specifies the magnitude (e.g., 5 V, 24 V, 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 percent of the input voltage rating.
- With DC input modules, the input voltage may also be expressed as an operating range (e.g., 24–60 volts DC) over which the module will operate.



❑ The I/O Section

❖ Discrete I/O Specifications

✓ INPUT THRESHOLD VOLTAGES

➤ This discrete input module specification specifies two values:

- 1- a minimum ON-state voltage that is the minimum voltage at which logic 1 is recognized as absolutely ON;
- 2- a maximum OFF-state voltage which is the voltage at which logic 0 is recognized as absolutely OFF.



❑ The I/O Section

❖ Discrete I/O Specifications

✓ 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.



❑ The I/O Section

❖ Discrete I/O Specifications

✓ 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.



❑ The I/O Section

❖ Discrete I/O Specifications

✓ 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 percent of the nominal output voltage rating.



❑ The I/O Section

❖ Discrete I/O Specifications

✓ 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*.



❑ The I/O Section

❖ Discrete I/O Specifications

✓ 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 volts AC, rates the module's capacity for sustaining an excessive voltage at its input or output terminals.
- Although this isolation protects the logic side of the module from excessive input or output voltages or current, the power circuitry of the module may be damaged.



❑ The I/O Section

❖ Discrete I/O Specifications

✓ 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.



❑ The I/O Section

❖ Analogue modules

✓ 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.



❑ The I/O Section

❖ Analogue modules

✓ 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.



❑ The I/O Section

❖ Analogue modules

✓ 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.

✓ 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), the more accurately an analog value can be represented.

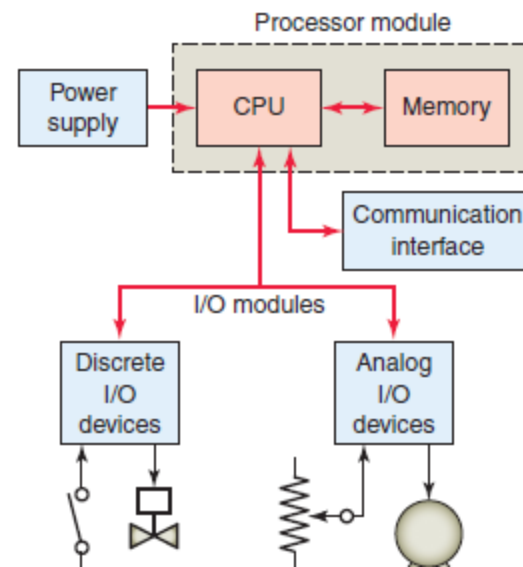
✓ INPUT IMPEDANCE AND CAPACITANCE

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



❑ The Central Processing Unit (CPU)

- Processors vary in processing speed and memory options.
- A processor module can be divided into two sections: the CPU section and the memory section.
- 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.

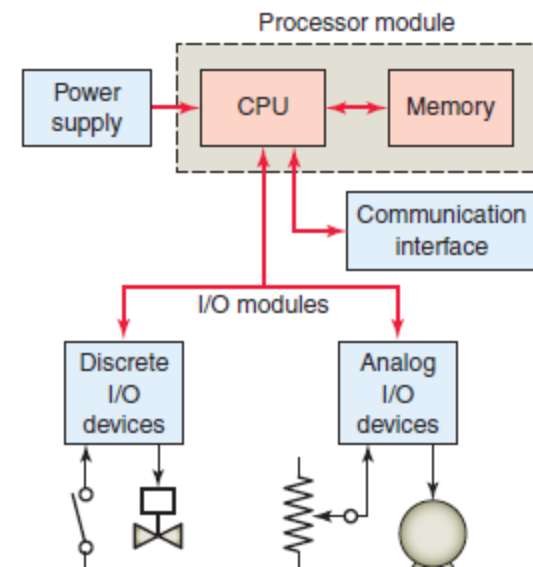




❑ The Central Processing Unit (CPU)

- The PLC power supply provides the necessary power (typically 5 VDC) to the processor and I/O modules
- 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.
- *Holdup time*, which is the length of time a PLC can tolerate a power loss, typically ranges from 10 milliseconds to 3 seconds.

The CPU executes the operating system, manages memory, monitors inputs, evaluates the user logic (I appropriate outputs.





❑ The Central Processing Unit (CPU)

- 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
- Associated with the processor unit will be a number of status LED indicators to provide system diagnostic information to the operator .
- Also, a keys wich may be provided that allows you to select one of the following three modes of operation: RUN, PROG, and REM.
- **RUN Position** :- Executes the ladder program and energizes output devices
- **PROG Position** :- Allows you to perform program entry and editing
- **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



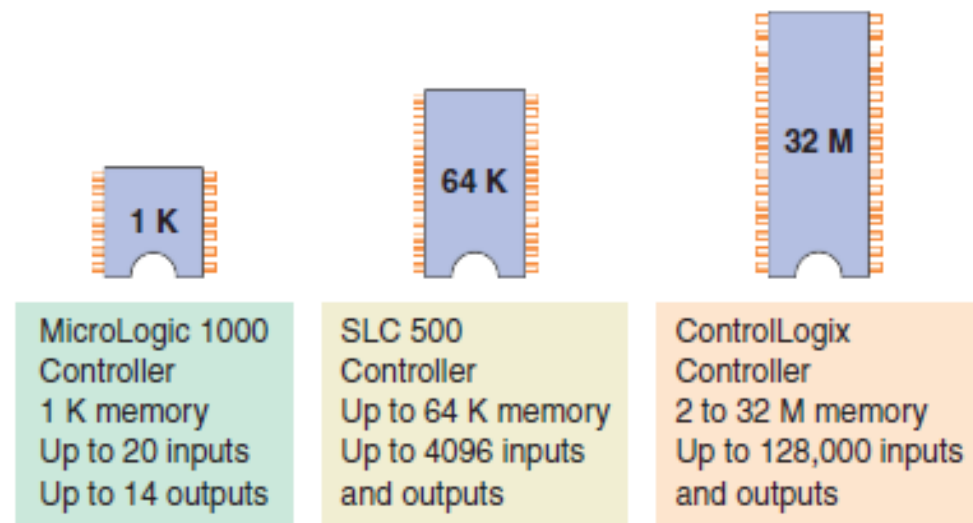
❑ Memory Design

- 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 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.



❑ Memory Design

- 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.
- 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





❑ Memory Design

- 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).
- 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

