CHAPTER

Input Modules

OBJECTIVES

After completing this chapter, you should be able to:

- describe the available types of input modules
- explain the differences between sinking and sourcing
- explain the correlation between positive and negative logic and sinking and sourcing
- explain how specialty I/O modules enhance a PLC's functionality
- define module and sensor specifications from data sheets
- list the advantages of three-wire solid-state sensors and the disadvantages of using two-wire sensors
- explain the differences between analog and discrete inputs

INTRODUCTION

The input and output section of a PLC system is the physical connection between the outside world and the CPU. A modular PLC uses interchangeable input modules. The modularity feature of a PLC and its ability to interchange modules to meet the immediate interface need makes the PLC so popular and versatile. Input modules are available to accept various voltages and currents and to automatically convert input signals into a logical (typically 5 V dc) signal with which the CPU can work. After solving the user program **logic** and sending the output signal to the output module by way of the output status file, the output module, which is also available in various switching configurations, controls field output devices. This means that a low-voltage (for example, 24 V dc) control signal can be an input controlling 240 VAC output devices.

There are various ways to get information into the CPU from common hardware field devices. First, discrete I/O interface modules provide a method of getting two-state discrete, or digital signals into and out of the PLC. Second, ever-changing signals such as temperature or pressure (called analog signals) can be interfaced to the PLC using modules specifically designed to accept these variable signals. These modules are called *analog input* or *analog output modules*. There are additional specialized modules that allow the PLC to accept specific variable input signals, including resistance temperature detector (RTD) or thermocouple.

This chapter introduces discrete and analog I/O modules, their operating principles, types of modules available, advantages of using one over the other, and basic interfacing principles.

INPUT MODULES

I/O modules are available as either input only, output only, or a combination of inputs and outputs. Figure 7-1 shows a four-slot Allen-Bradley SLC 500 modular chassis and an I/O module being inserted.

In the figure, the module slides into the rack or chassis on the grooves visible on the inside bottom of the chassis. Also notice the self-locking tabs, which will lock the module

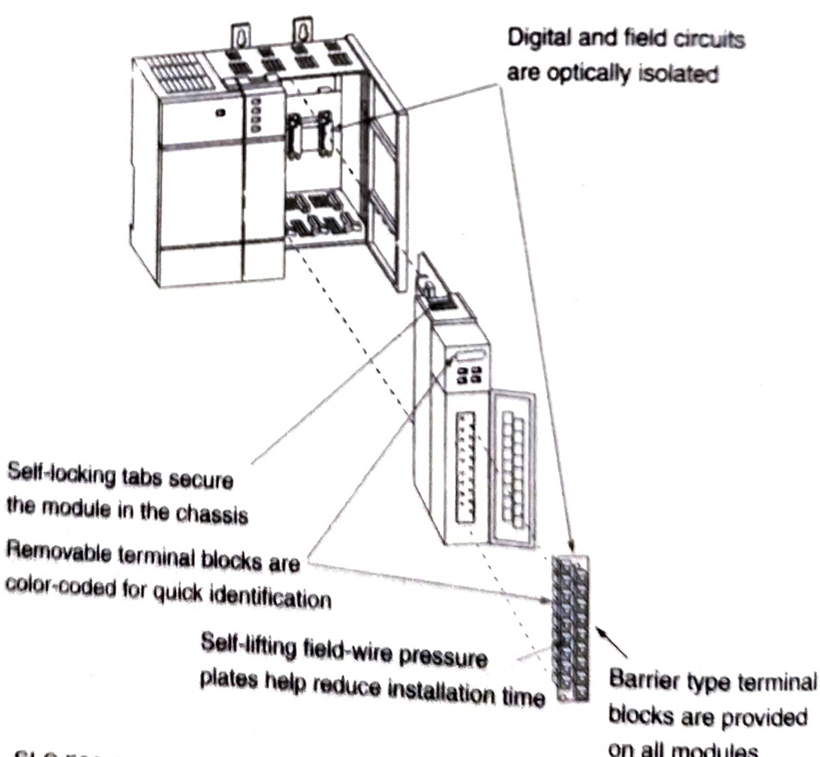

Figure 7-1 SLC 500 four-slot chassis with I/O module to be inserted. (Used with permission of Rockwell Automation, Inc.)

into the chassis. An I/O module is made up of the following features: at the very top of the module is identification indicating whether this is an input, output, or combination module. Some manufacturers color-band the identifications portion of the module for further identification. Figure 7-2 illustrates an SLC 500 combination I/O module. Directly below the identification portion lie the status indicators. There will be one status indicator, or light-emitting diode (LED), for each I/O point. These lights alert the operator to the ON or OFF status of each point on that module. Farther down the front of the module are the screw terminals for connecting the I/O wires to the module. Removable terminal blocks make wiring and changing the module easy and avoid the need for rewiring.

Some manufacturers place the I/O connections behind a hinged door, as illustrated in Figure 7-2. There may be an area on the inside of the module door to identify each I/O

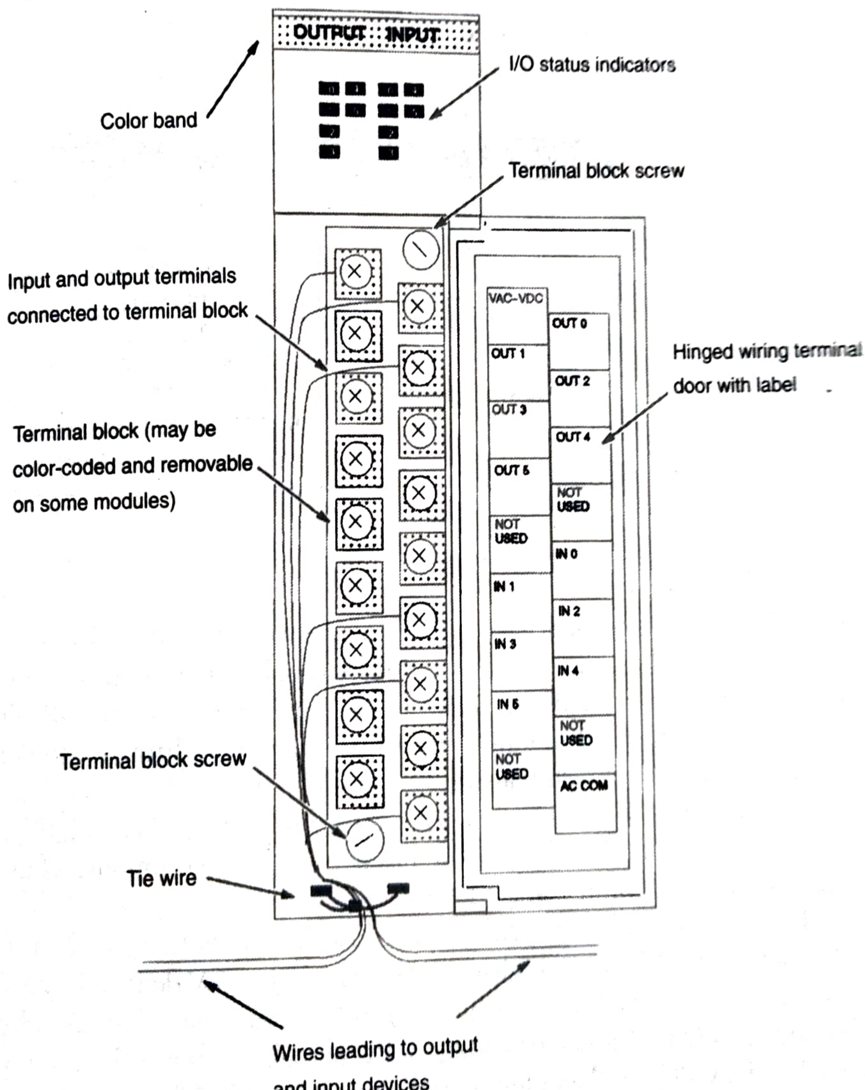

Figure 7-2 SLC 500 combination I/O module. (Used with permission of Rockwell Automation, Inc.)

screw terminal. Notice that each terminal on this combination module is identified as simply OUT 0, OUT 1, OUT 2, . . . and IN 0, IN 1, IN 2, ... This identifies outputs 0 through 5 and inputs 0 through 5 for this module. To build the entire input and output address, the chassis slot in which a module is placed determines the rest of the I/O address for each specific point.

Discrete input modules are selected according to the voltage levels with which they can work. Typical input modules can accept +5 V dc, 10–30 V dc, 120 VAC, 120–240 VAC, and 200–240 VAC levels as inputs.

DISCRETE INPUT MODULE

The discrete input module is the most common input interface used with programmable controllers. Discrete input signals from field devices can be either AC or DC. The most common module types are listed below:

AC INPUT MODULES	DC INPUT MODULES
24 VAC	24 V dc
48 VAC	48 V dc
120 VAC	10–60 V dc
240 VAC	120 V dc
Nonvoltage	230 V dc
120 Volts Isolated	Sink/Source 5–50 V dc
240 Volts Isolated	5 V dc TTL level
24 VAC/DC	5/12 V dc TTL (transistor–transistor logic) level

DISCRETE AC INPUT MODULE

A 120 VAC input module will accept signals between 80 and 135 VAC. Common inputs include limit switches, proximity switches, photoelectric switches, selector switches, relay contacts, and contact closures from other equipment. Figure 7-3 illustrates wiring for a typical 120 VAC input module. Signals from line one through the field input device are wired to input screw terminals on the module. The left module has its commons connected internally. All inputs will have the same voltage. The right module is a 120 or 230 VAC input module. The module has two separate commons, which allows the user to wire two different input voltage levels.

The input module is considered the load for the field input device. The module's job is to convert the 120 VAC, high-voltage signal to the 5 V dc level, with which the PLC can work. The module's job is to verify the input as a valid signal, isolate the high-voltage field device signal from the lower-voltage CPU signal, and send the appropriate ON or OFF signal to the CPU for placement in the input status file. The circuitry contained in an input module is composed of three parts: power file conversion, isolation, and logic, as illustrated in Figure 7-4.

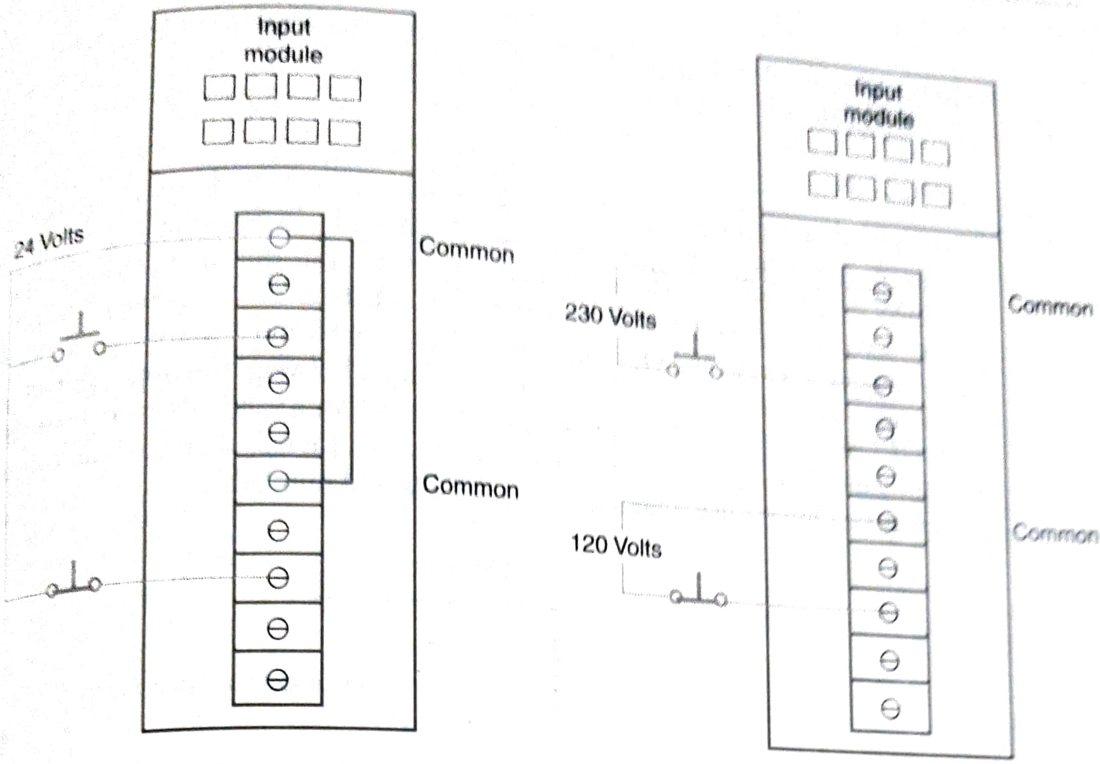

Figure 7-3 Typical wiring of input signals into a 120-VAC eight-point input module.

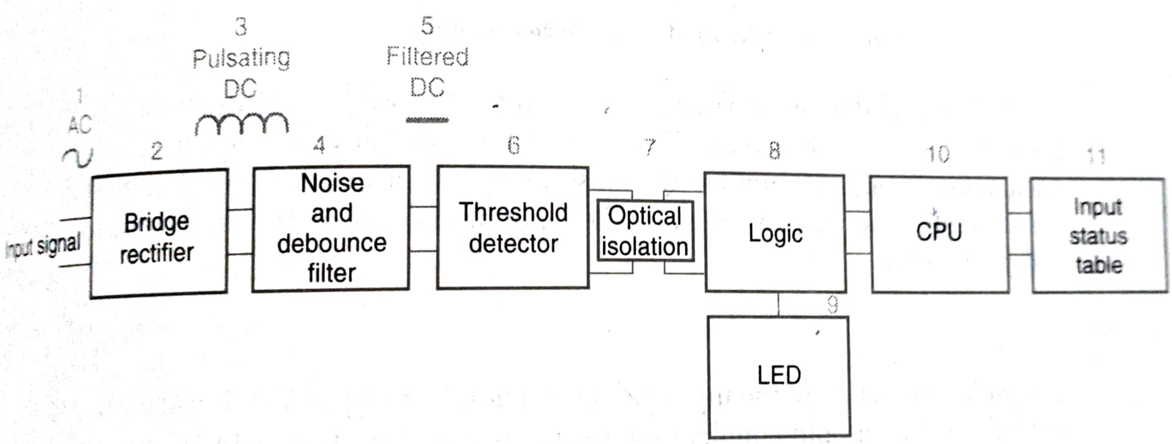

Figure 7-4 Block diagram of a typical AC input circuit.

Alternating current enters the input module (section 1) and then flows to the power conversion section (section 2).

Power Conversion

The power conversion section usually consists of resistors and a bridge rectifier. The bridge rectifier converts the incoming AC signal to a pulsating DC level (see section 3 of Figure 7-4). The DC level is passed through filters and other logic (section 4) to deliver a clean, debounced, DC input signal (section 5). The filtered DC signal goes on to the threshold detector (section 6).

Threshold Detection

Threshold detection circuitry detects if the incoming signal has reached or exceeded a predetermined value for a predetermined time, and whether it should be classified as a valid ON or OFF signal. Module specifications call this the valid ON/OFF state voltage range. A typical valid OFF state is between 0 and 20 or 30 VAC, depending on the module's manufacturer. A valid ON state will be between 80 and 132 VAC, again depending on the manufacturer (see Figure 7-5). The signal area between the upper voltage limit for a valid OFF state (20 volts) and the minimum voltage for a valid ON state (80 volts) is called the undefined, or input state not guaranteed, zone. Signals falling within this undefined area may be ON or OFF, making them unstable and unreliable.

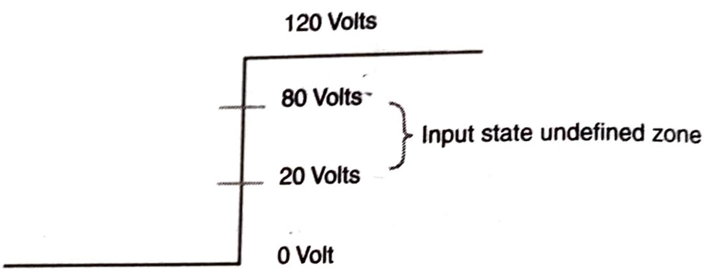

Figure 7-5 Input pulse with valid signal areas defined.

Filtering and time delays are used to filter out possible electrical noise that may be interpreted as a *false* input pulse. To eliminate the possibility of faulty operation due to electrical noise, a valid AC input signal must not only be a specific value, but must be present for a specific amount of time before the input module allows the valid signal to pass to the isolation section.

Isolation

The isolation section of the input circuit (section 7 of Figure 7-4) is usually made up of an optical isolator, or opto-coupler as it is sometimes called. In a 120 VAC input module, isolation separates the high-voltage, 120 VAC input signal from the CPU's low-voltage control logic. The low-voltage control logic signals associated with the CPU will run from 5 to 18 V dc, depending on the module manufacturer and the type of logic employed.

Isolation is accomplished by the input signal energizing a light-emitting diode (LED), which transmits a signal of light energy to a receiver in the form of a photo-conductive diode. Simply put, the LED converts the electrical signal to an optical signal. The receiver, usually a photo-transistor, converts the optical signal back to an electrical signal. An optical isolator works similarly in principle to the sun shining on a solar cell. Think of the LED shining light on the photo-transistor as the sun. The solar cell converts the light into electrical current. There is no actual physical or electrical coupling between the sending LED, its associated input circuitry, and the optical receiver and its low-voltage, associated logic circuitry. The signal is transferred by light from the LED. Figure 7-6 illustrates a simplified optical isolator.

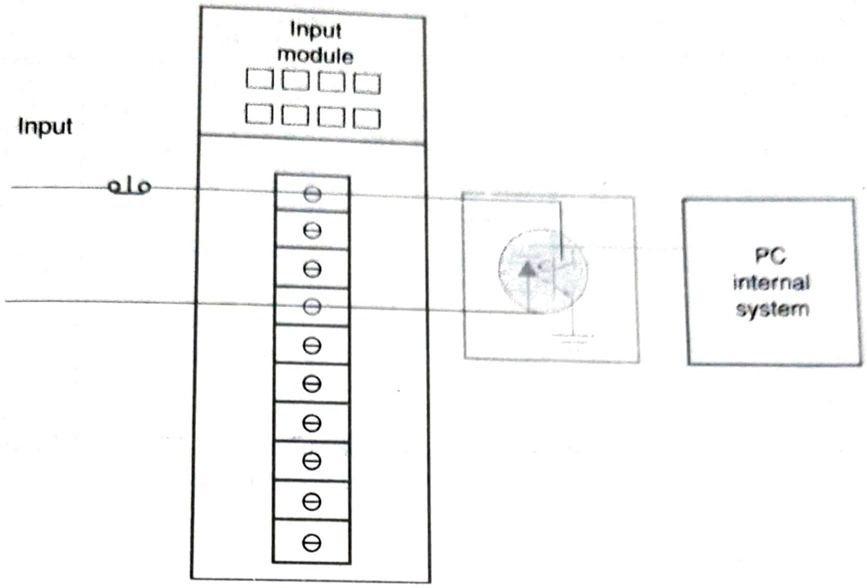

Figure 7-6 Optical isolator to isolate high-voltage incoming signals from the CPU's lower voltage levels.

Optical isolation protects the low-voltage CPU and its associated circuitry by preventing spikes or high-voltage transients on the input circuit from transferring into the low-voltage circuitry.

The Logic Section

DC signals from the opto-coupler are used by the logic section (section 8, Figure 7-4) to pass the input signal to the module's input address LED (section 9) and the CPU (section 10), and then on to the *input status file* via wires on the rack's backplane called the data bus.

AC INPUT MODULE SPECIFICATIONS

Now that we understand how an AC input module conditions, verifies, and passes an input signal on to the CPU, we will look at input module specification data.

Module specifications provide important information during module selection, PLC *hardware* configuration, troubleshooting, and input device selection. Figure 7-7 contains typical AC input specification data. Each specification will be discussed in the following pages.

Voltage	Inputs	Points per Common	Backplane Current Draw at 5 V dc	Maximum Signal Delay	Maximum Off-State Current	Input Current Nominal	Maximum Inrush Current
85 to 132 VAC	4	4	0.035 Amps	ON = 35 ms OFF = 45 ms	2 mA	12 mA at 120 VAC	0.8 A
	8	8	0.050 Amps	ON = 35 ms OFF = 45 ms	2 mA	12 mA at 120 VAC	0.8 A
	16	16	0.085 Amps	ON = 35 ms OFF = 45 ms	2 mA	12 mA at 120 VAC	0.8 A
170 to 265 VAC	4	4	0.035 Amps	ON = 35 ms OFF = 45 ms	2 mA	12 mA at 240 VAC	1.6 A
	8	8	0.050 Amps	ON = 35 ms OFF = 45 ms	2 mA	12 mA at 240 VAC	1.6 A
	16	16	0.085 Amps	ON = 35 ms OFF = 45 ms	2 mA	12 mA at 240 VAC	1.6 A

Figure 7-7 AC input module specifications for Allen-Bradley SLC 500 120-VAC and 240-VAC input modules. (Table compiled from Allen-Bradley Discrete I/O modules data)

Explanation of Figure Headings

Voltage: This is the operating voltage at 47 to 63 hertz (Hz) for the module.

Inputs: This indicates the number of inputs the module has.

Points per Common: This is the number of input points that share the same common connection. As an example, one 16-point input module could have all input points sharing one common, and a different 16-point input module might have two groups of 8 input points. Each group of 8 would have its own separate common. Figure 7-8 illustrates a 16-point input module with two groups of 8 inputs and their respective common terminals.

Backplane Current Draw: Each module takes power from the PLC's power supply to operate the electronics on the module. This specification will be used when calculating power supply loading. We will explore power calculations in Chapter 9. In the lab exercises for Chapter 9, you will calculate power for two PLCs, an SLC 500, and a General Electric Series 90-30.

Maximum Signal Delay: Signal delay is the time it takes for the PLC to pick up the field input signal, digitize it, and store it in memory. This specification is usually listed for a signal turning on and for a signal turning off.

Nominal Input Current: This is the current drawn by an input point at nominal input voltage.

Maximum Inrush Current: This is the maximum inrush current the module can handle.

Maximum Off-State Current: This is the maximum amount of current, typically from leakage from a solid-state input device, that a module can accept while remaining in an OFF state.

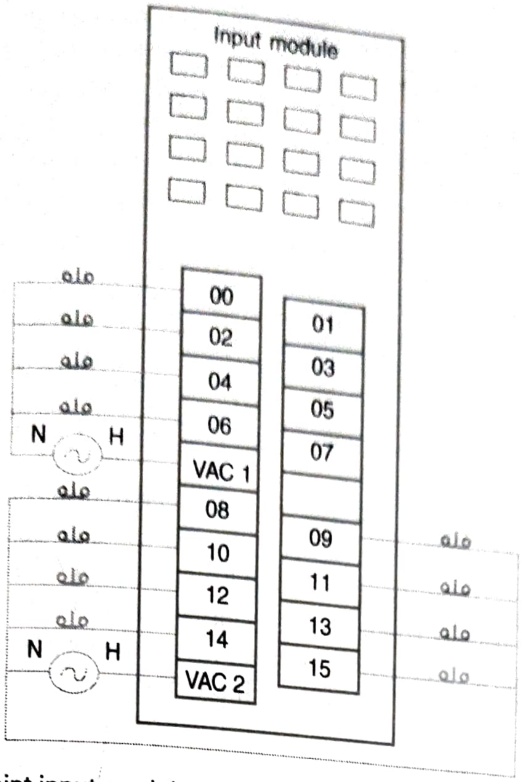

Figure 7-8 Sixteen-point input module with eight points per common.

Additional Module Specifications: In addition to the specifications already mentioned, there are four additional module specifications, sometimes difficult to find, that are important when replacing a mechanical AC limit switch with a solid-state style proximity device. When interfacing an AC, two-wire, solid-state sensor to a PLC, voltage drop, leakage current, minimum load current, and power-up delay are specifications not normally associated with mechanical limit switches, and need to be considered when replacing a mechanical input device with a solid-state device.

The Two Types of Input Devices

There are two types of input devices commonly interfaced to an input module. One type includes the mechanical limit switch, toggle switch, selector switch, push button, and contacts from an electromechanical relay. Every one of these devices has something in common: circuit continuity is either made or broken by physically opening a set of contacts. When open, these contacts have a physical air gap; thus, there is infinite resistance, resulting in zero current flow through the physically open contacts. Since these are mechanical contacts, there is no electrical power required to make the device operate.

The second type, the solid-state proximity device, on the other hand, is an electronic device, which means that it needs power to operate. A small amount of current must continuously flow through the device, even in the OFF state, to keep the internal electronics working so that the switch will be able to sense the presence of an object. Figure 7-9 illustrates a two-wire connection for a solid-state proximity sensor. Notice that there is only a single path for power flow, not only to provide the ON or OFF signal to the load, but also to provide that small amount of current to operate the internal electronics. The current flowing through the sensor to operate the internal electronics is called its "leakage current."

Figure 7-9 Two-wire solid-state sensor. The load usually will be a PLC input module.

This is an interesting concept that we need to investigate: the current leaking from our AC input devices. Excessive leakage current could possibly cause an input module's input point to turn on in error if the module's maximum OFF-state current is exceeded. Figure 7-10 illustrates two inputs going into an input module. Input A is a mechanical limit switch. When the limit switch is open, there exists a physically open circuit; thus, there is zero current flow into input point 0. Input 6 is an inductive proximity switch. Although the

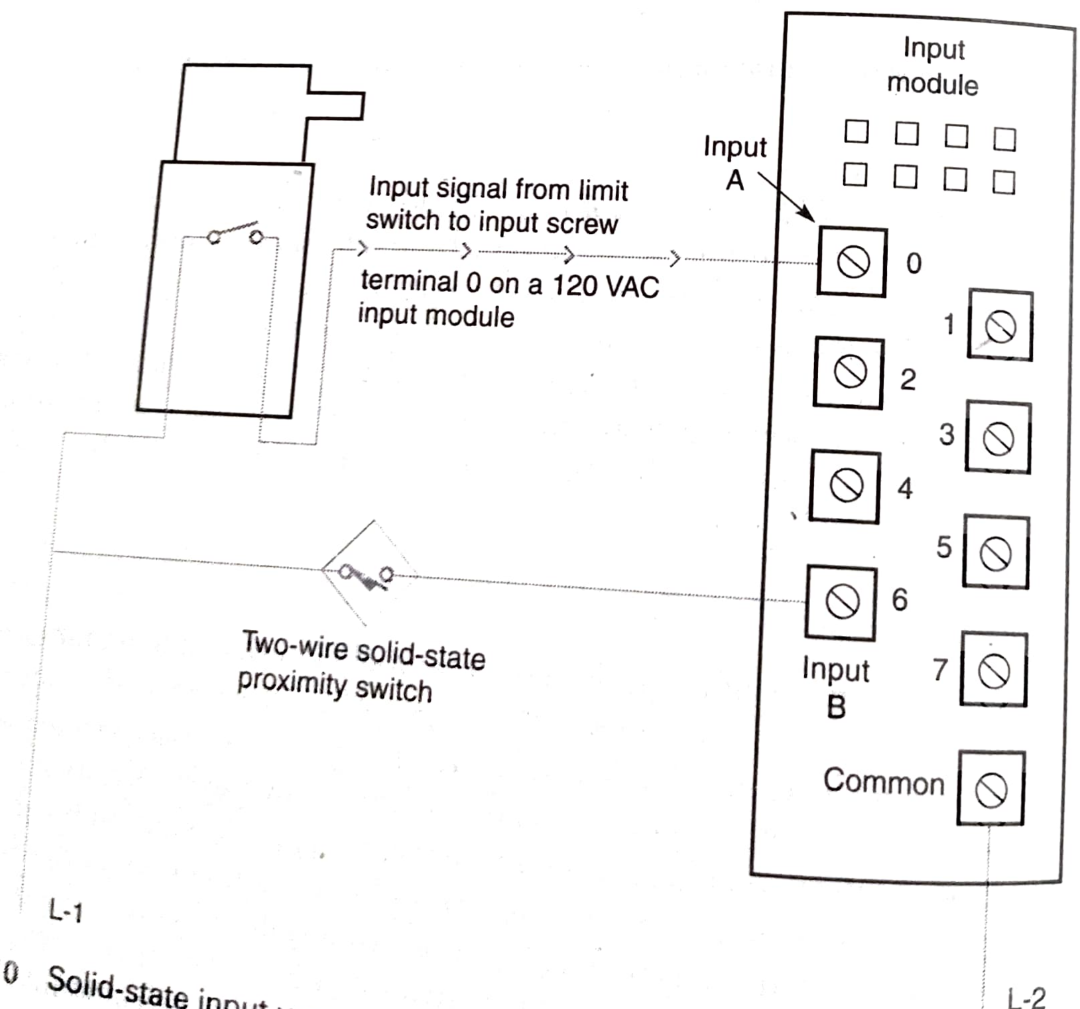

Figure 7-10 Solid-state input versus a mechanical switch as input to an input module.

switch is in the OFF, or deenergized, state and the schematic symbol shows an open circuit, there must be current flow through the electronics to keep the sensor operating so that it will be able to switch from open to closed when a target comes into range.

Leakage current for a two-wire sensor is typically less than 2 milliamps (usually around 1.7 mA). Some larger, high-power sensors can have leakage current as high as 3.5 mA or more. Most sensor manufacturers have a standardized leakage current value of less than 2 mA so that they can interface to most PLCs. A typical AC input module will accept leakage current of less than 2 mA and still read the signal as a valid OFF. Figure 7-11 illustrates a normally open, solid-state input circuit with the sensor seeing no object. The input module screw terminal to which this sensor is wired is in the OFF state. An amp meter shows the circuit's leakage current.

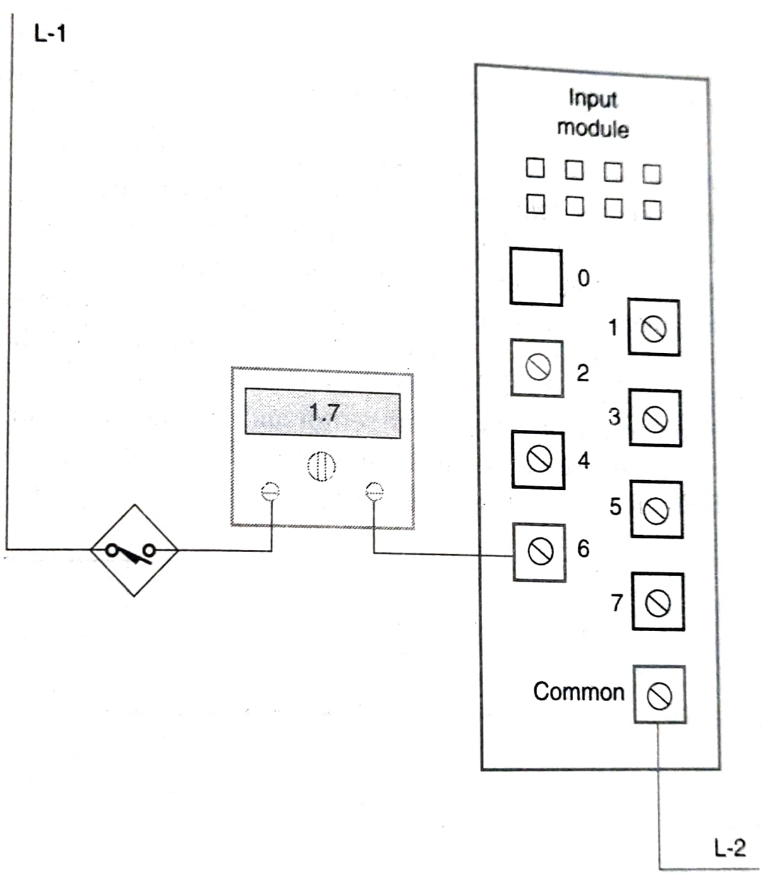

Figure 7-11 Amp meter showing leakage current in a two-wire DC sensor input circuit.

Current multiplied by the amount of voltage equals the amount of operating power. The voltage drop across the input device multiplied by the leakage current equals the voltage available to the device. The higher the voltage drop, the higher the available power. However, the higher the voltage drop across the input device, the less voltage is available for the input module, which is the load in an input circuit. Voltage drop specifications for a specific input device will be found in the sensor's specification sheets. Typically, two-wire, solid-state input devices will have a voltage drop of between 6 and 10 volts. Power supplied to the input module from the sensor must be above the minimum ON-state voltage and minimum ON-state current for the module to see a valid ON signal.

Another consideration is the power-up delay time. Consider the following input circuit, in Figure 7-12.

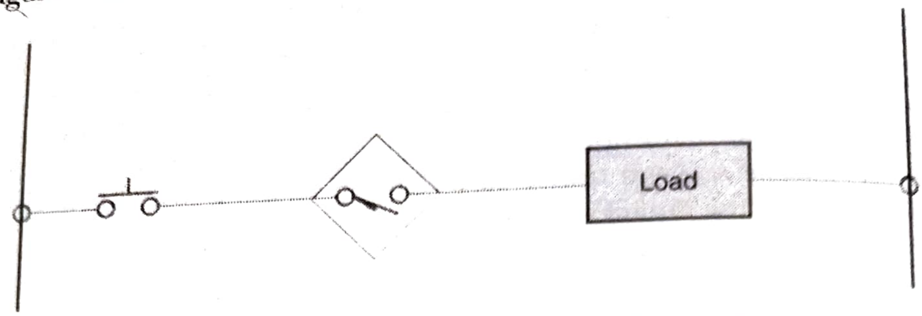

Figure 7-12 Mechanical switch in series with solid-state AC two-wire sensor.

The mechanical switch, in series with the sensor, creates an open circuit to the solid-state sensor. For the solid-state proximity sensor to operate properly, it needs to be powered continuously. Being in an open circuit, the sensor is not operating; thus, it cannot sense an object in the sensing zone. If an object appears in front of the sensor and the push button is depressed, the sensing device will not be available to see the target until the electronics inside the sensor become operational. This delay time is called the "power-up delay" or the "time delay before availability." This time delay can range from 8 milliseconds (ms) up to 100 milliseconds, depending on the sensor and the manufacturer. Because of this phenomenon, wiring any two-wire, solid-state sensor in series with a mechanical switch should be avoided. Figure 7-13 illustrates power-up delay between a push button and a sensor.

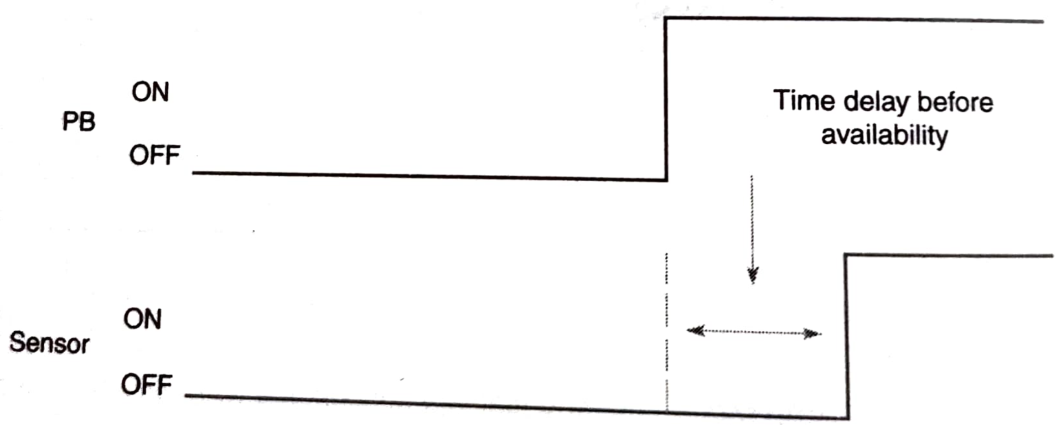

Figure 7-13 Time delay before sensor availability.

There is a solution to the time delay. You can place a resistor in parallel to the mechanical switch to permit enough leakage current to flow to keep the sensor alive for instantaneous operation. The resistor should be sized to provide the leakage current as listed in your sensor specification sheet. Assuming a 115 VAC circuit and a sensor with a 1.7 mA leakage current specification, how do you calculate the value of the resistor?

Resistance (R) = voltage (V) divided by leakage current (I)
R = V/I
R = 115/.0017
R = 67,647

Based on the calculations, you should select a 67 K (67,000) ohm resistor; typically a 1-watt resistor will be used. Figure 7-14 illustrates the input circuit with the proper bypass resistor. The bypass resistor will allow enough current in the circuit to keep the sensor ready.

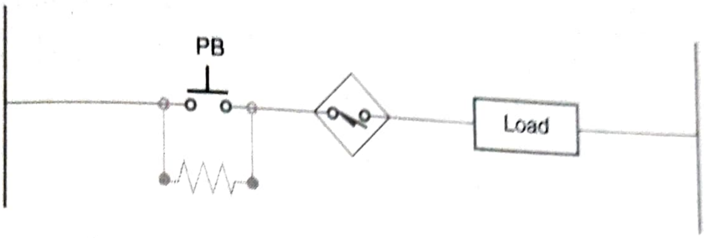

Figure 7-14 **Resistor in parallel with input push button to solve time delay before sensor availability.**

Minimum Load Current

A two-wire, solid-state sensor requires a minimum current flow to stay alive. If the load has a high impedance, a loading resistor should be placed in parallel with the load to dissipate excessive leakage current.

DC INPUT MODULES

Next, we will investigate DC input modules, operating principles, specifications, selection, operation, and interface. Low-voltage, 24 V dc inputs are commonly used for start/stop control circuitry and sensor interface to the PLC.

DC sensors can drive electromechanical relays, counters, and solenoids in addition to solid-state devices. A DC sensor will interface directly to a PLC without additional interface circuitry when using the proper DC input module. Common industrial sensing applications use discrete, solid-state sensors with transistor outputs for interfacing to PLCs. These sensing devices include inductive proximity sensors, capacitive proximity sensors, and photoelectric sensors, to name a few. Typical industrial sensors that fall into this category are 10–30 V dc sensors.

The sensor's transistor switch controls the signal that is input into a PLC DC input module. Transistors are solid-state switching devices that are available in two different polarities, NPN or PNP. NPN and PNP are descriptions of the two basic types of transistor. By selecting the transistor switching configuration to match the DC polarity of your DC input module, the sensor can be incorporated into any polarity input circuit.

Solid-state input devices with NPN transistors are called "sinking input devices," and input devices with PNP transistors are called "sourcing input devices."

SINKING AND SOURCING

"Sinking" and "sourcing" are terms used to describe current flow through a field device in relation to the power supply and the associated I/O point. Probably the most common PLC interface situation that involves sinking or sourcing occurs when choosing and interfacing a common inductive proximity or photoelectric sensor to a PLC.

The problem with defining sinking and sourcing circuits is that the definition changes depending on whether you are an engineer or a technician. Typically, engineering schools teach one theory, but technical schools may teach another.

The first question we must answer is: In which direction does the current flow? Figure 7-15 illustrates a battery, toggle switch, and light bulb. This is a simple circuit; however, even so simple a circuit can fuel an argument as to which way current is flowing.

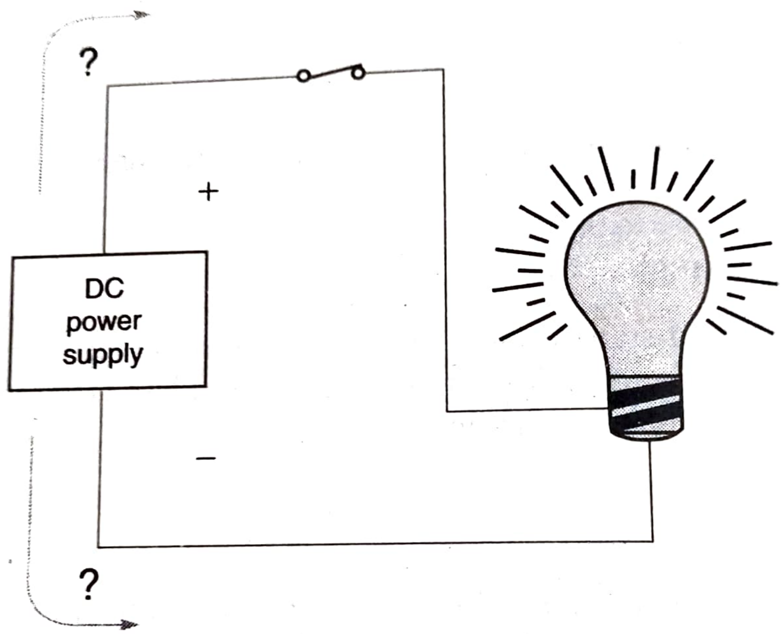

Figure 7-15 Current flow in a simple battery-powered lamp circuit.

On the one hand, many engineering school students and graduates will argue that current flows from the positive side of the battery through the circuit, and returns to the negative side of the battery. On the other hand, many technical school students will argue that current flows from the negative side of the battery through the circuit, and returns by way of the positive terminal of the battery. So what is the correct answer? As a rule of thumb, refer to your particular PLC manufacturer's literature to determine how your PLC handles sinking and sourcing modules and their interface.

There is a commonly accepted definition about what a sinking and sourcing I/O circuit looks like; however, not all manufacturers use the same terminology. Many PLC manufacturers follow the theory that current flows from positive to negative, the theory we will use in this text.

In a DC circuit there must be three pieces: power, a switching device, and the load. The relationship between the switching device, the load, and which one receives current first, defines whether we have a sinking or sourcing circuit. Figure 7-16 illustrates the switch and light circuit we looked at in Figure 7-15. Current flows from the positive terminal of the battery through the switch and onto the light, which is the load. Notice that the switch is the source of current as far as the light is concerned. As a result, the switch is called a sourcing device. The light is then a sinking device, as it sinks the current to ground.

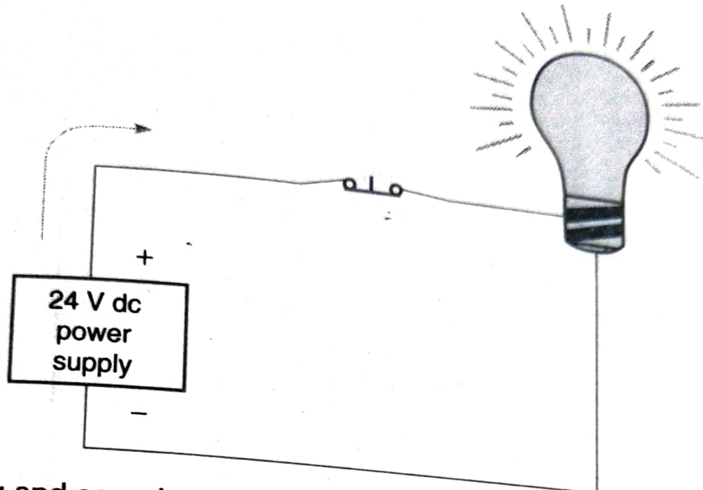

Figure 7-16 Sinking and sourcing DC circuit. The switch is the source of current that the light sinks to ground.

On the flip side is the opposite circuit. Figure 7-17 illustrates the current flow from the positive side of the battery to the light. The light is then the source of the current as it passes it to the switch, which in turn sinks the current to ground.

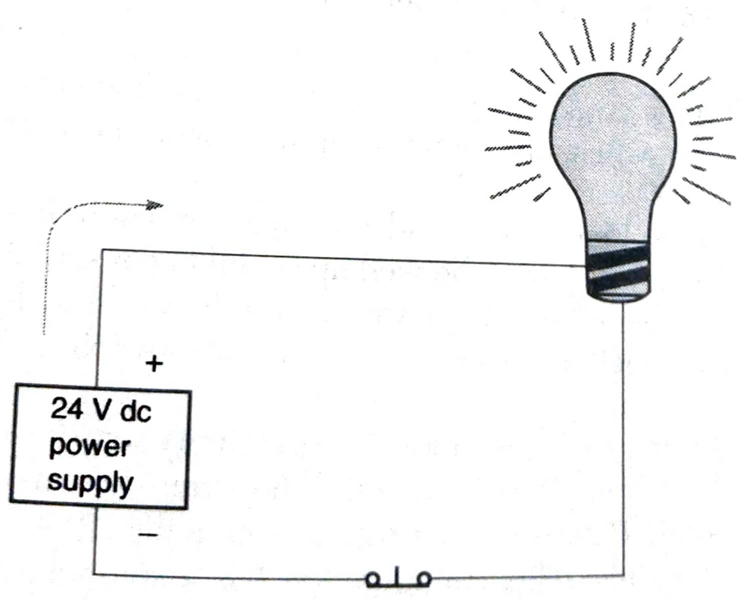

Figure 7-17 Sinking and sourcing DC circuit. The light is the source of current that the switch sinks to ground.

Figure 7-16 illustrates a sourcing switch with a sinking light, whereas Figure 7-17 illustrates a sourcing light with a sinking switch. If we modify Figure 7-17 to include an input module as the load rather than the light, the principles of sinking and sourcing remain the same. Figure 7-18 illustrates a sourcing input module, the load, with a sinking switch.

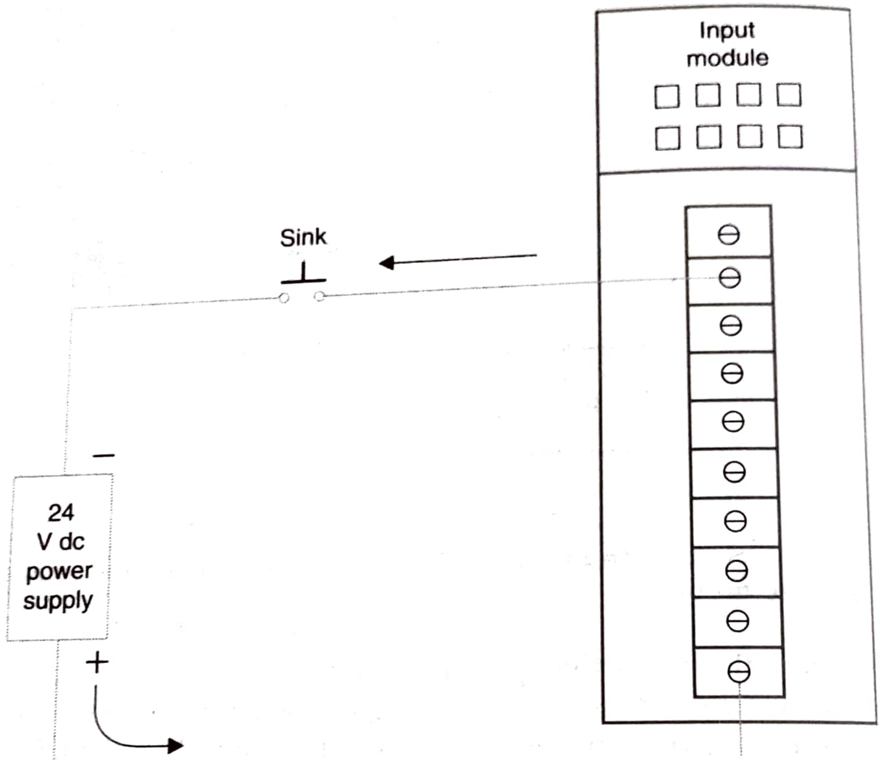

Figure 7-18 Sourcing DC input module with a sinking switch.

Figure 7-19 is a sinking input module. Current flows from the positive side of the battery through the switch, our sourcing input device. The switch is the source of current to the input module.

The circuits in Figures 7-16 and 7-17 may seem as if they would function the same regardless of whether they were hooked up as sinking or sourcing. Neither the toggle switch nor the light is affected by which way current flows through it. Nonetheless, a solid-state transistor device such as an inductive proximity switch is very particular as to how it is hooked up.

The solid-state, switching, inductive proximity sensor uses a transistor as its switching device. For these transistors to operate, they must be wired correctly to the appropriate DC input module. Figure 7-20 illustrates a sourcing (PNP) sensor interfaced to a 24 V dc sinking input module. This configuration has a sourcing sensor (PNP transistor) as an input to a sinking input module.

Figure 7-21 illustrates a sinking (NPN) sensor interfaced to a 24 V dc sourcing input module. The PLC module is also the source of current to the sensor, which makes it a sourcing input.

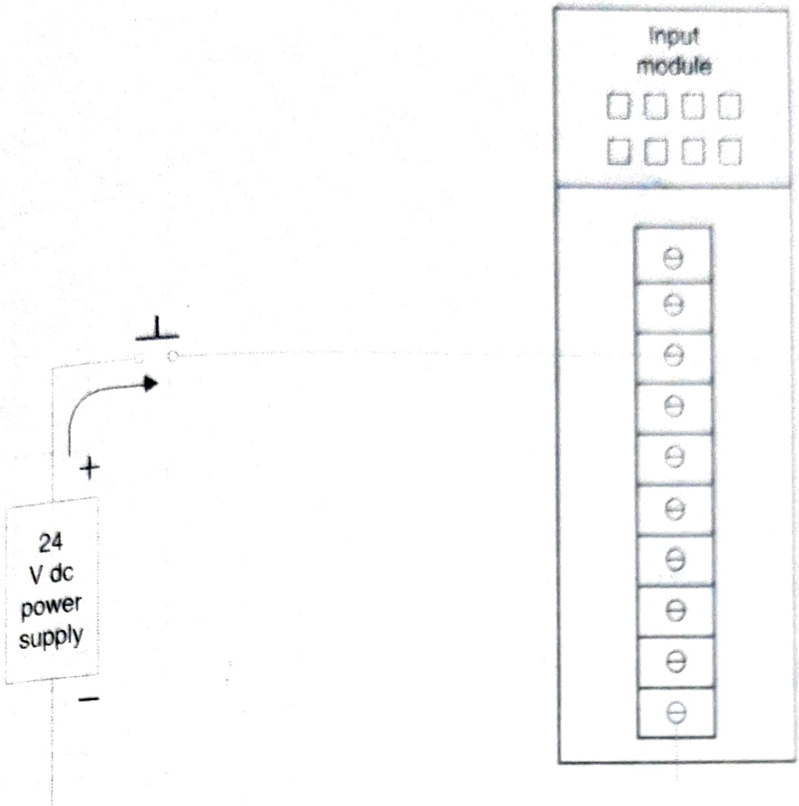

Figure 7-19 Sinking DC input module with a sourcing switch.

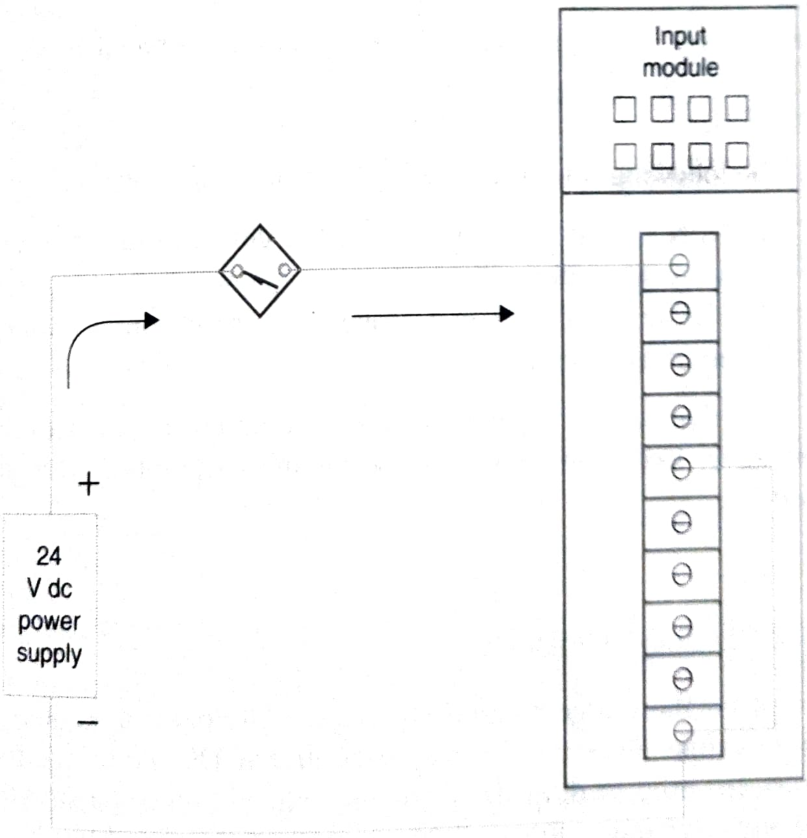

Figure 7-20 Sourcing two-wire inductive proximity sensor interfaced to a sinking 24-V dc input module.

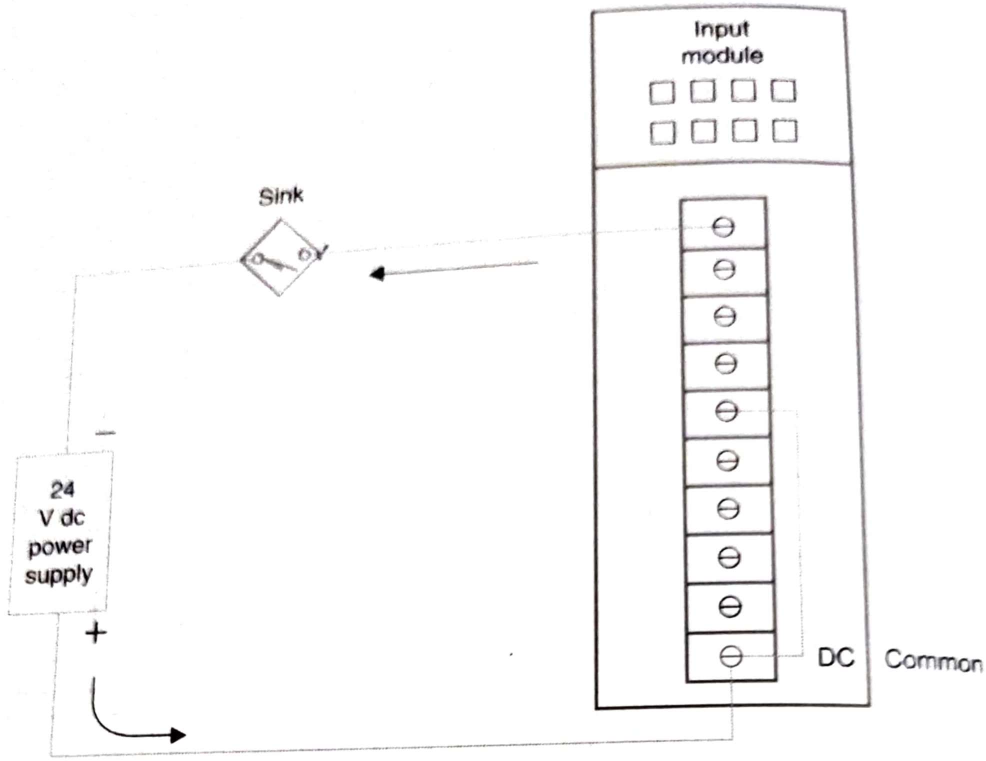

Figure 7-21 Sinking two-wire inductive proximity sensor interfaced to a sourcing 24-V dc input module. This proximity sensor sinks current to ground or the negative side of the power supply. This sensor has an NPN transistor as its switching device.

The following two basic principles pertain to sinking and sourcing circuits:

1. NPN transistors are open-collector, current-sinking devices, which interface to a sourcing input module.
2. PNP transistors are open-collector, current sources, which interface to a sinking input module.

Now that we have defined sinking and sourcing and the two classes of DC input modules, let us look more closely at the modules, operating principles, specifications, and interface.

DC INPUT MODULE OPERATION

Except for the bridge rectifier circuit, the DC input module is very similar to the AC input module. Since the input signal is already DC, no bridge rectifier is necessary. Resistors are used to drop the incoming voltage before passing the signal on to the remaining electronics. Figure 7-22 illustrates a simplified block diagram for a DC input module.

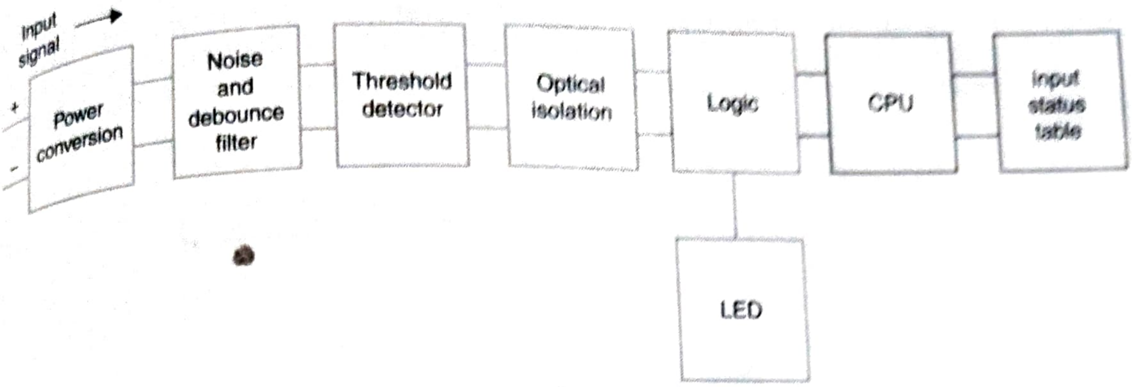

Figure 7-22 Simplified circuitry for a DC input module.

DC SINKING INPUT MODULE SPECIFICATIONS

Now that we understand the basic types, operation, and interface of field devices to a DC input module, let us look into DC input module specifications, as illustrated in Figure 7-23.

Voltage	Inputs	Points per Common	Backplane Current Draw at 5 V dc	Maximum Signal Delay	Maximum Off-State Current	Input Current Nominal	Maximum Off-State Voltage
10 to 30 V dc Sink	8	8	0.050 Amps	ON = 8 ms OFF = 8 ms	1 mA	8 mA at 24 V dc	5 V dc
	16	16	0.085 Amps	ON = 8 ms OFF = 8 ms	1 mA	8 mA at 24 V dc	5 V dc
	32	8	0.106 Amps	ON = 3 ms OFF = 3 ms	1 mA	8 mA at 24 V dc	5 V dc

Figure 7-23 DC input module specifications for Allen-Bradley SLC 500 sinking inputs. (Data compiled from Allen-Bradley DC input module data sheets)

Analysis of New Table Terms

Many of the terms used for DC input module specifications are the same as for AC input modules. Only new terms will be discussed here.

Maximum Off-State Current This is the maximum amount of leakage current allowed in an input circuit from an input device that will keep the input circuit in an OFF state.

If more leakage current flows through the sensor than the maximum current needed to keep the module's input point (maximum off-state current) in the OFF state, the input module will see a valid ON signal all the time. Figure 7-24 illustrates a typical two-wire connection to its load. When connecting input devices to PLCs, the input point is the load.

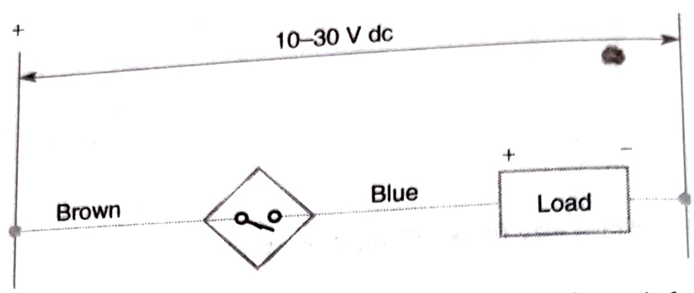

Figure 7-24 Two-wire sensor connected to its load. Notice single path for current to flow.

There are three ways to eliminate the problem of leakage current; first, carefully match the input device and the input module. If the leakage current specification of the sensing device is more than the maximum off-state current the module will accept for a valid OFF condition, choose a different input device.

If using a two-wire sensor is necessary, a bleeder resistor can be inserted into the circuit to bleed current around the load. Each sensor manufacturer has its own resistor selection chart or formula in the sensor data or specification information. Figure 7-25 is an excerpt from an Allen-Bradley bleeder resistor selection chart, in the booklet, "Inductive and Capacitive Sensor and Programmable Controller Interface Manual Preferred Compatibility." For ease of illustration, only one input module has been selected from the available tables. To determine the necessary bleeder resistor, locate the particular SLC 500 input module in the tables in the book. For this example we have chosen the Allen-Bradley SLC 500 input module 1746-IB16. If the sensor's leakage current was 2.0 milliamps, you would locate the proper bleeder resistor at the point where the 2.0 milliamp column intersects with the desired input module. Looking at Figure 7-25, a 1 K ohm resistor is the correct choice. The booklet's text will direct you to select a 3-watt resistor.

ALLEN-BRADLEY BLEEDER RESISTOR SELECTION CHART				
SLC 500 Input Module	Input Module Maximum Off-State Current	Bleeder Resistor Selection per Sensor Leakage Current		
		1.5 milliamps	2.0 milliamps	2.5 milliamps
1746-IB16	1 milliamp	1.5 K ohm	1 K ohm	750 ohm

Figure 7-25 SLC 500 1746-IB16 module bleeder resistor selection data. (Data from Allen-Bradley data tables)

If you need to calculate a bleeder resistor, refer to your sensor manufacturer's calculation method to determine the resistor for your application. The bleeder resistor is installed similar to the illustration in Figure 7-26.

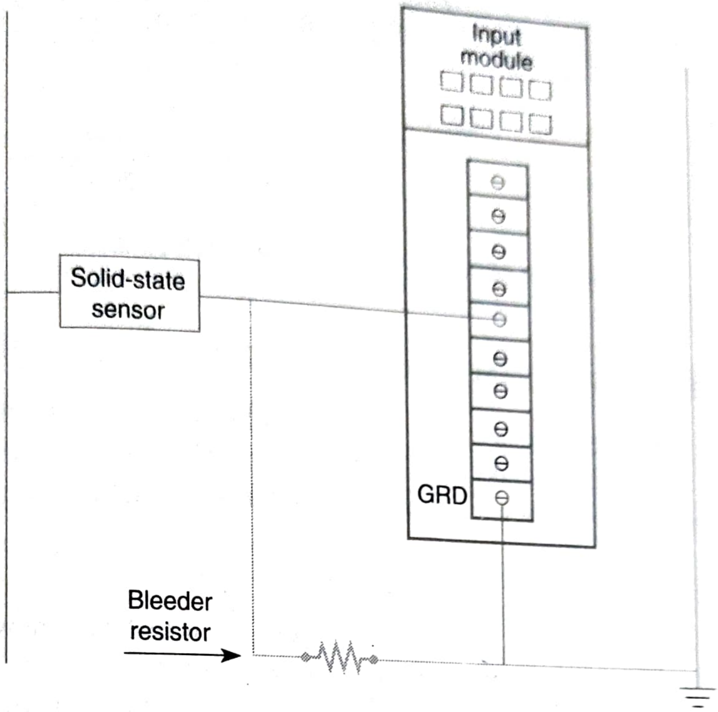

Figure 7-26 Bleeder resistor installation in an input circuit.

The object of the bleeder resistor is to create a parallel circuit so that excess current is shunted away from the input point. As an example, suppose the input impedance of the input module's input point is 1 K ohm. If the leakage current of the sensor is 1.7 milliamps and we put a 1-K ohm resistor in parallel with the input (as illustrated in Figure 7-26), we split the current going into the input module in half. The input module receives .85 milliamps, while the other .85 milliamps are shunted to ground through the bleeder resistor. With the input point receiving .85 milliamps and a maximum off-state current specification of 1 milliamp, there should be no problem with the input signal and the module.

The third option is to choose a three-wire input device. Figure 7-27 illustrates a three-wire inductive proximity switch and three-wire connection to the load. The brown wire provides current flow into the sensor to operate the sensor electronics, along with current for the input signal into the PLC input module. The third wire in Figure 7-27, the blue wire, provides a path for current from the operation of the sensor's internal electronics to the return to ground without affecting the load. The result is a separate circuit for the sensor's internal electronics and a separate signal for the sensor's input signal to the PLC.

We have introduced issues when interfacing a solid-state sensor to DC input modules. Let us look at a practical example of interfacing an actual sensor to a selected manufacturer's 24 V dc input modules.

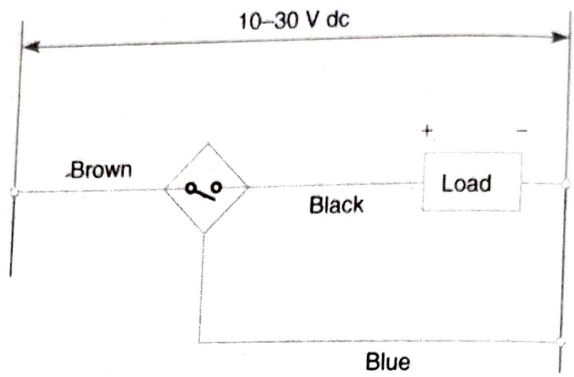

Figure 7-27 Diagram of connection for three-wire sensor.

SOLID-STATE SENSOR INTERFACE TO DC INPUT MODULES

We are going to interface selected two- and three-wire inductive proximity sensors to different 24 V dc input modules. First, let us interface a two-wire Allen-Bradley 871 TM DC inductive proximity sensor to an SLC 500 input module.

Sensor Interface to SLC 500 DC Input Module

Say we have an application where we need to interface a new sensor to an existing SLC 500 PLC system. The application requires sensing a mild steel target at a range of 8 millimeters. We have three input modules available in the SLC 500 chassis. The module part numbers are: 1746-IA16, 1746-IB8, and 1746-IV8. Module specifications are listed in Figure 7-28.

Module Specification	MODULE CATALOG NUMBERS		
	1746-IA16	1746-IB8	1746-IV8
Operating Voltage	85–132 VAC	10–30 V dc Sink	10–30 V dc Source
Number of Inputs	16	8	8
Points per Common	16	8	8
Backplane Current Draw at 5 V dc	.050 A	.085 A	.085 A
Maximum Signal Delay	ON = 35 ms OFF = 45 ms	ON = 8 ms OFF = 8 ms	ON = 8 ms OFF = 8 ms
Maximum Off-State Current	2 mA	1 mA	1 mA
Maximum Off-State Voltage		5 V dc	5 V dc
Nominal Input Current	12 mA at 120 VAC	8 mA at 24 V dc	8 mA at 24 V dc
Maximum Inrush Current	.8 A	NA	NA

Figure 7-28 Selected SLC 500 input module specifications. (Data from Allen-Bradley data tables)

Three Allen-Bradley inductive proximity sensors are available for this application. The available sensors and their specifications are listed in Figure 7-29.

Sensor Specifications	SENSOR CATALOG NUMBERS		
	872C-D8NE-18-A2	871TM-DH4NE-12-A2	871TM-DH8NE-18-A2
Operating Voltage	10–55 V dc Source	10–30 V dc Source	10–30 V dc Source
Barrel Diameter	18 mm	12 mm	18 mm
Sensing Distance	8 mm	4 mm	8 mm
Shielded	No	No	No
Output Configuration	Normally Open	Normally Open	Normally Open
Switching Frequency	500 Hz	75 Hz	50 Hz
Load Current	5–200 mA	<25 mA	<25 mA
Minimum Load Current		2 mA	2 mA
Leakage Current	<1.5 mA	<.9 mA	<.9 mA

Figure 7-29 **Selected Allen-Bradley sensor specifications. (Data compiled from Allen-Bradley data tables)**

We must select the correct sensor module pair and perform the wiring. We need to ask the following questions:

1. Are the available sensors AC or DC? The three sensors will operate on 10 to 30 V dc.
2. We need to select a DC input module. The 1746-IA16 input module is eliminated as it is an 85–132 VAC input module.
3. We have sinking and sourcing input modules available, but do we have both sinking and sourcing sensors available? No, all available sensors are in the sourcing configuration. From our lessons in the text we have learned that if we have a sourcing sensor, we must choose a sinking input module. For this application we will choose the 1746-IB8, a sinking input module. Always verify wiring diagrams before choosing one. Compare input module wiring with the sensor's wiring diagrams, as in Figure 7-30.
4. Is leakage current from the input sensor a problem? Leakage current from the sensor specifications is listed at <0.9 milliamps for two sensors and <1.5 milliamps for the third. The 1746-IB8 maximum off-state current is listed at 1 milliamp. The sensor with <1.5 milliamp leakage exceeds the module's maximum off-state current. This sensor must be rejected unless a bleeder resistor is to be used. The two remaining sensors should be acceptable from the standpoint of leakage current.
5. What sensor will provide us with the appropriate sensing distance? The 871TM-DH8NE-18-A2 will sense mild steel at an approximate range of 8 millimeters (mm). This sensor will fit our application.

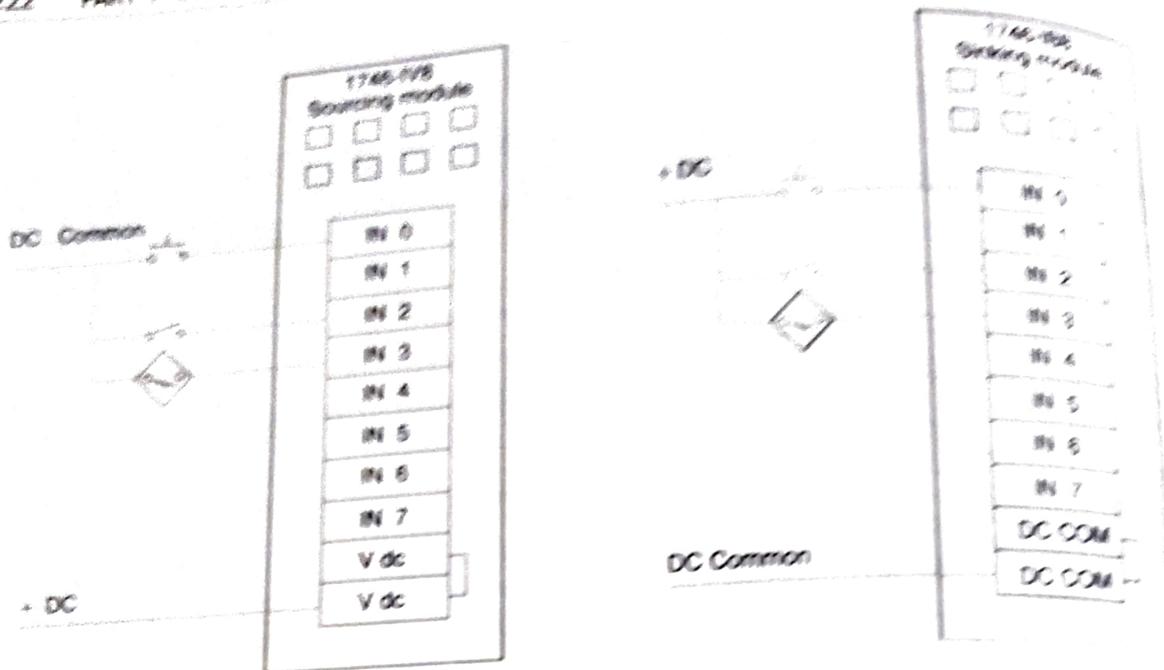

Figure 7-30 Wiring diagrams for the Allen-Bradley SLC 500 1746-IV8 and 1746-IB8. (Used with permission of Rockwell Automation, Inc.)

A FINAL NOTE ON SINKING AND SOURCING

There is one final consideration before leaving the topic of sinking and sourcing. We are going to introduce a possible safety consideration. Consider Figure 7-31. The left, PNP circuit is reportedly more common in Europe, while the right, NPN configuration is more common in the United States. Do you see any safety issues regarding one of these configurations? Looking at the NPN configuration, what would happen if the load developed a short to ground? Would not the load start, or turn on, unintentionally? This may be a consideration when deciding if an input device should be sinking or sourcing.

Before we conclude our study of input modules, we must look at how a PLC interfaces to analog input signals. While discrete signals are simply two-state signals, analog input modules give the PLC the ability to monitor an ever-changing input signal, such as temperature or pressure.

ANALOG INPUTS

Typical analog signals come from temperature, pressure, position, and revolutions per minute (RPM) inputs. Simply, analog input modules convert analog signals to digital words. Analog input modules are selected to accept either a current or a voltage input signal. Input signal levels are usually either 0 to 10 V dc, −10 to +10 V dc, 0 to 5 V dc

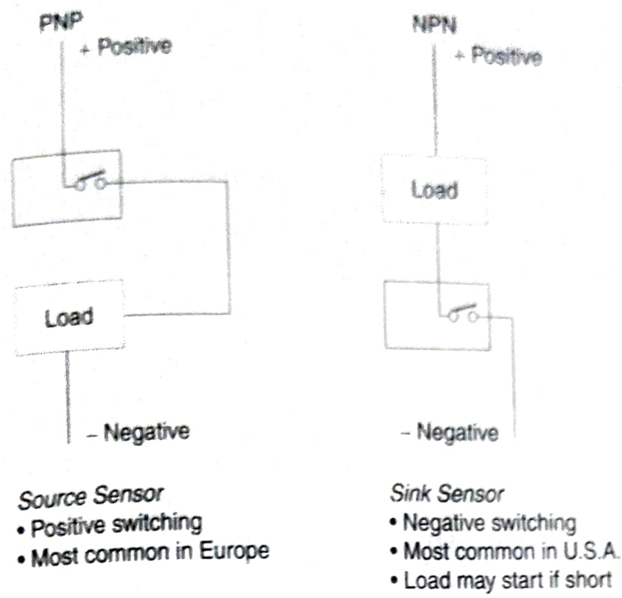

Figure 7-31 **PNP versus NPN and safety issues.**

1 to 5 V dc, 0 to 20 milliamps, −20 to +20 milliamps, or 4 to 20 milliamps. Analog modules convert the analog input signal through an analog-to-digital converter (A-to-D or A/D converter), and thus to a digital signal. Figure 7-32 illustrates a block diagram of a single-channel input for an IC693ALG222 voltage analog input module for the General Electric Series 90-30 PLC. Notice the A/D converter, which converts the analog input voltage to a digital signal. The digitized signal is passed through optical isolation to an onboard microprocessor and then on to the backplane of the baseplate. The backplane transfers the digitized signal to the CPU and on to the data table for storage.

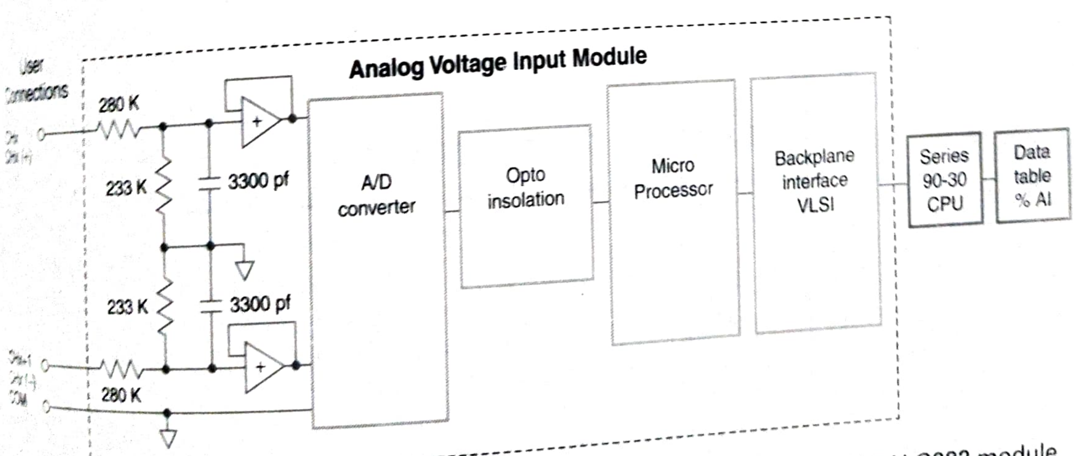

Figure 7-32 **Analog voltage input module block diagram for a General Electric IC693ALG222 module. (Courtesy of GE Fanuc Automation)**

Input modules come in three configurations: all inputs, all outputs, and combinations of inputs and outputs. Figure 7-33 lists the available General Electric (GE) Series 90-30 analog modules. An input to, or output from, an analog module is called a "channel."

GENERAL ELECTRIC SERIES 90-30 ANALOG MODULES		
GE Catalog Number	Module Description	Channels
IC693ALG220	Voltage Analog Input	4
IC693ALG221	Current Analog Input	4
IC693ALG222	Voltage Analog Input	16
IC693ALG223	Current Analog Input	16
IC693ALG390	Analog Output	2
IC693ALG391	Analog Output	2
IC693ALG392	Analog Output	8
IC693ALG422	Combination Analog Module Current/Voltage	4 In 2 Out

Figure 7-33 **General Electric Series 90-30 analog modules. (Courtesy of GE Fanuc Automation)**

As an example, a PLC can be set up to monitor the temperature in an oven baking cookies. The oven temperature's lower limit could be 340 degrees, while the set point might be 350 degrees. An ever-changing analog temperature value will be input into the PLC. Oven temperature will gradually fall from the set point of 350 degrees to 340 degrees, as illustrated in Figure 7-34. The PLC will be programmed so that when the temperature has fallen to 340 degrees it will turn on the heaters to warm the oven back to its

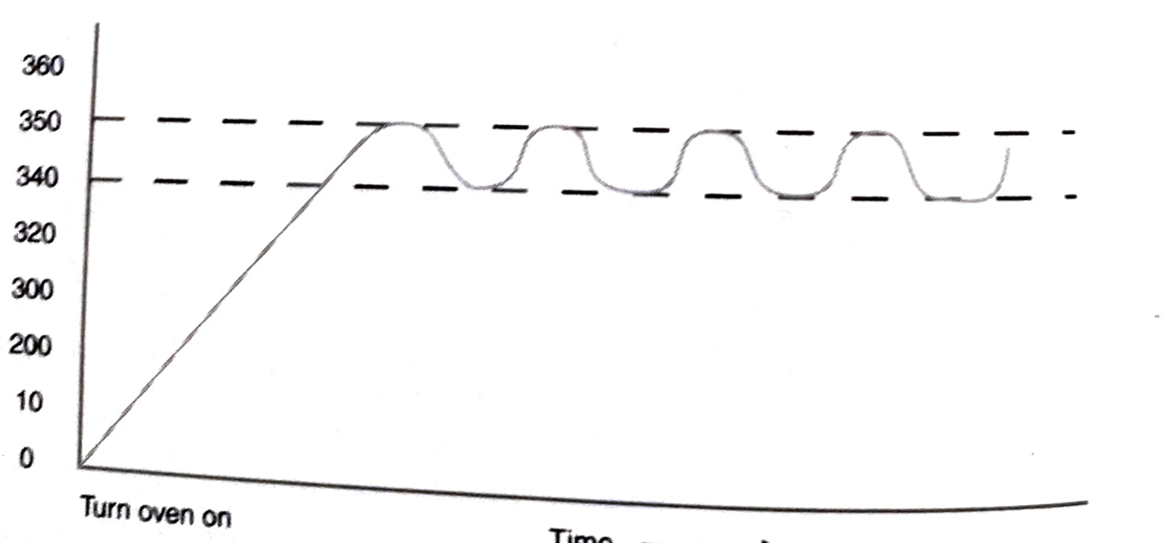

Figure 7-34 **Oven temperature correlation to time.**

set point. As the PLC continues to monitor the rising oven temperature, the heaters will be turned off when the analog input signal corresponds to 350 degrees.

In another example, let us assume that we have a one-turn potentiometer interfaced to a PLC input module. The potentiometer is used by a process operator to vary the speed of a variable-speed drive controlling a mixer. As the operator turns the potentiometer up from zero to full, the voltage varies in a linear fashion from 0 to 10 volts. The graph in Figure 7-35 illustrates the potentiometer position from 0, which is minimum, to 10, full open, to illustrate the voltage input into our analog input module.

POTENTIOMETER POSITION IN COMPARISON TO INPUT VOLTAGE										
100%										X
90%									X	
80%								X		
70%							X			
60%						X				
50%					X					
40%				X						
30%			X							
20%		X								
10%	X									
0%	1	2	3	4	5	6	7	8	9	10
Input Voltage increasing →										

Figure 7-35 Potentiometer knob position in relation to input voltage signal seen by input analog module.

Let us interface the potentiometer from Figure 7-35 to an Allen-Bradley SLC 500. The input module converts the analog input signal through its internal analog to a digital converter to a 16-bit data word. The digital equivalent of the analog value is sent on to the input status file input word associated with the input slot in which the analog module resides. Each analog input or output connection is called a channel. Figure 7-36 lists Allen-Bradley's SLC 500 analog modules.

Each channel will be represented as one 16-bit word in either the input status or output status files. If an analog input module has two channels, there will be two words of input status file space needed to store the binary representation of the analog voltage or current signal. Likewise, a four-channel input analog module will require four words in the input status file represented by the slot in which the module resides. Considering that a typical discrete input or output module only gets one 16-bit word in the status table, how is analog channel data stored in the status table?

ALLEN-BRADLEY SLC 500 ANALOG MODULES		
Catalog #	Input Channels per Module	Output Channels per Module
1746-NI4	4 differential, voltage or current	None
1746-NI8	8 differential, voltage or current	None
1746-NI16I	16 single-ended, current	None
1746-NI16V	16 single-ended, voltage	None
1746-NIO4I	2 differential, voltage or current	2 current
1746-NIO4V	2 differential, voltage or current	2 voltage
1746-NO4I	None	4 current
1746-NO4V	None	4 voltage
1746-FIO4I	2 differential, voltage or current, selectable	2 current
1746-FIO4V	2 differential, voltage or current, selectable	2 voltage

Figure 7-36 Selected Allen-Bradley SLC 500 analog modules. (Data compiled from Allen-Bradley SLC 500 Analog Modules specification data)

Analog Input Status Word Addressing

A 16-point input module residing in slot three will be addressed as I:3, 0 through 15. A modular SLC 500 with 16-point modules in slots two, three, and four would be represented in the input status table as illustrated in Figure 7-37.

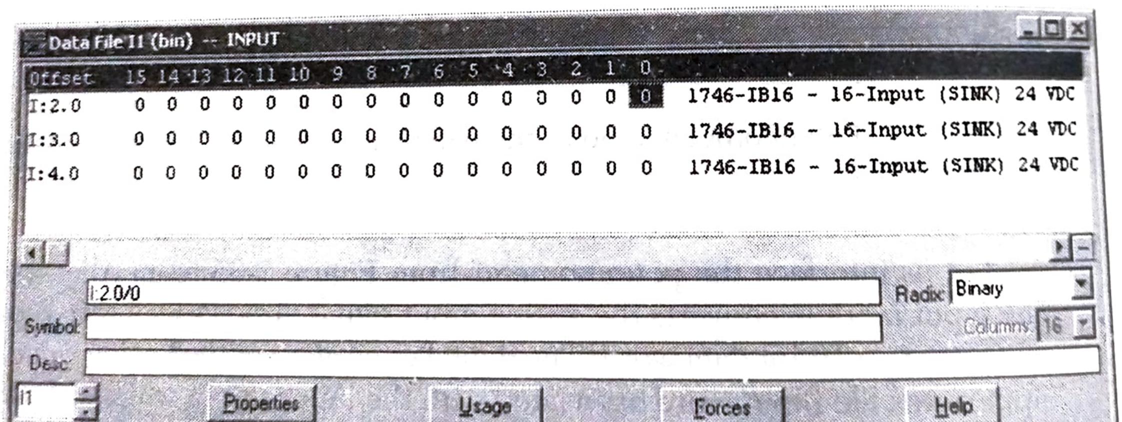

Figure 7-37 RS Logix 500 input status table representation for input modules in slots two, three, and four.

If more data must be stored in the input status table for a particular slot, additional words are available. When only 16 bits of input data need to be stored in the input status table, the CPU will only assign and use one word, word zero. The input address is usually written simply as I:3, followed by the screw terminal number. However, the input address may be written more formally to reflect the word designation. The formal address for an SLC 500 is I:3.0, screw terminal number. Notice the .0 after the slot designation. This designates the word number. The first word is always word zero. When a module needs more than one word, the I/O configuration process for an SLC 500 PLC automatically assigns the required number of input and output status table words. Figure 7-38 illustrates an SLC 500 input status table with a 16-input discrete module in slot two and a 1747-SDN DeviceNet scanner module in slot three. The DeviceNet scanner module is a good example of the principle, as it is assigned 32 input words and 32 output words. The scanner module is used to communicate with a DeviceNet network.

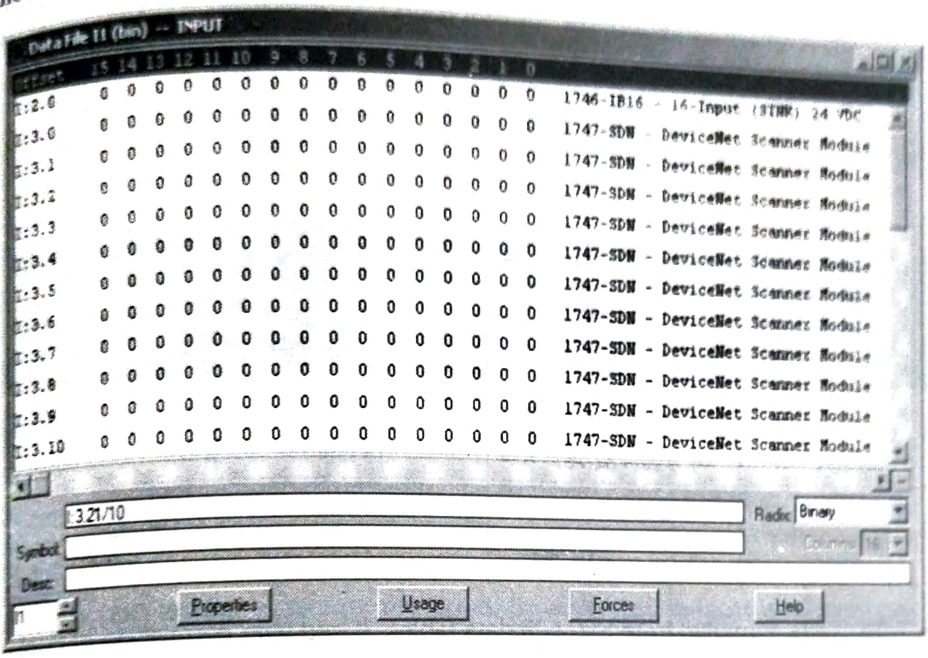

Figure 7-38 SLC 500 input status table showing word zero through word 10 for a 1747-SDN DeviceNet scanner.

A four-channel analog input module would be addressed as illustrated in Figure 7-39. The input status file addresses from Figure 7-39 represent the following:

I:2.0 is the input word for the 16-point module in slot two.

I:3.0 is analog input module, slot three, channel zero.

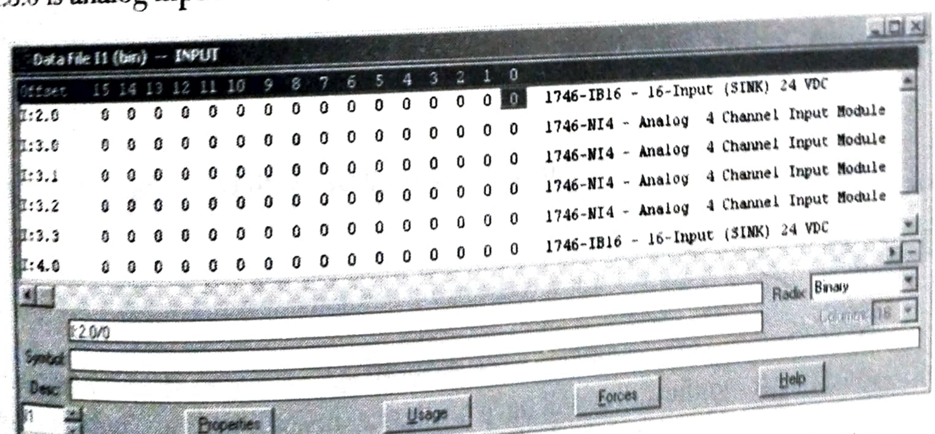

Figure 7-39 RS Logix 500 input status table reflecting words available for slot three.

I:3.1 is analog input module, slot three, channel one.
I:3.2 is analog input module, slot three, channel two.
I:3.3 is analog input module, slot three, channel three.
I:4.0 is the input word for the 16-point module in slot four.

Analog channel data will be stored in its respective words in the input status table. For example, the SLC 500 PLC analog input modules accept current or voltage input signals. The acceptable input signals are listed in Figures 7-40 and 7-41 along with signal specifications. Figure 7-41 lists analog current input specifications for the SLC 500. The far right column of Figures 7-40 and 7-41 refers to least significant bit "resolution." The resolution of an analog module is the weight assigned to the least significant bit.

SLC 500 ANALOG VOLTAGE INPUT SPECIFICATIONS			
Voltage Range	Decimal Equivalent	Significant Bits	Least Significant Bit Resolution (in Microvolts)
−10 V to +10 V	−32,768 to +32,767	16 bits	305.176 uV
0 V to 10 V	0 to +32,767	15 bits	305.176 uV
0 V to 5 V	0 to 16,384	14 bits	305.176 uV
1 V to 5 V	3,277 to +16,384	14 bits	305.176 uV

Figure 7-40 Data compiled from SLC 500 data tables. (Used with permission of Rockwell Automation, Inc.)

SLC 500 ANALOG CURRENT INPUT SPECIFICATIONS			
Current Range	Decimal Equivalent	Significant Bits	Least Significant Bit Resolution (in Microvolts)
−20 mA to +20 mA	−16,384 to +16,384	15 bits	1.22070 uV
0 to +20 mA	0 to 16,384	14 bits	1.22070 uV
4 to +20 mA	3,277 to 16,384	14 bits	1.22070 uV

Figure 7-41 Data compiled from SLC 500 data tables. (Used with permission of Rockwell Automation, Inc.)

Analog Module Resolution

After an analog input signal is sent through the analog-to-digital converter, the digitized word's least significant bit will have a value associated with it. This value is determined by the number of bits into which the analog-to-digital converter breaks the converted signal.

As an example, let's say we have a 0–10 volt analog input signal. Our analog-to-digital converter breaks the signal up into 10 parts. The closest we could measure a voltage input from this module would be to 1/10 of the 10-volt value, or 1 volt. Thus, the resolution would be 1 volt. This coarse resolution would not be acceptable in many applications. What if we represent the digitized value of the analog-to-digital converter with an 8-bit data word? An 8-bit word is equivalent to 255. If we divided a 0–10 volt analog signal into 255 parts, the least significant bit would be 1/255 of the 0–10 volt signal. Ten volts divided into 255 parts is equal to .0392 volts per part. Thus, the least significant bit (the smallest part) is equal to .0392 volts. This would be the resolution of the least significant bit if our input module resolved the 0–10 volt analog input signal through the A-to-D converter into an eight-bit data word.

Figure 7-40 lists the SLC 500 input module with a 0–10 volt analog input signal converted into 15 significant bits. A 15-bit word is equivalent to 32,767 in decimal. That means that a 15-bit word contains 32,767 parts. If 10 volts is divided into 32,767 parts, the least significant bit would be equal to .0003051 volts. This value is the same as the 305.176 microvolts listed in Figure 7-40.

Applying an Analog Input Module

Let us look at an example applying an analog input module. A 0–10 volt analog input signal from the potentiometer described earlier will be an input to channel one of an SLC 500 analog input module. Our analog input module will reside in slot three of an SLC 500 chassis. The converted binary data will be found in the input status table word address I:3.1 (input, slot three, word 1).

A four-channel analog input module would be addressed as illustrated in Figure 7-42. If the potentiometer was inputting 10 volts from a 0–10 volt signal, binary data would be represented as illustrated in the address I:3.1 in Figure 7-42.

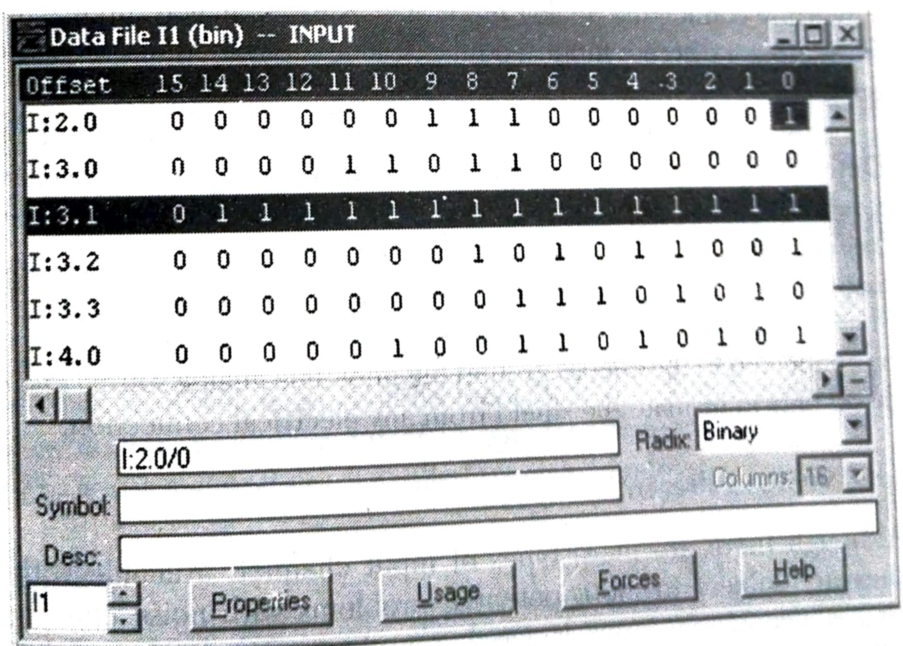

Figure 7-42 RS Logix 500 input status table reflecting words available for slot three.

Figure 7-43 illustrates the decimal value of the binary value stored in the input data file word representing voltages from 0 to 10 volts for that input channel.

ANALOG SIGNAL COMPARISON FOR SAMPLE POTENTIOMETER INPUT		
Potentiometer Position	Voltage Input Signal	Decimal Value Represented in Data PLC's Table
100%	10	32,767
80%	8	26,214
70%	7	22,937
60%	6	19,660
50%	5	16,384
40%	4	13,107
30%	3	9,830
20%	2	6,553
10%	1	3,276
Closed	0	0

Figure 7-43 Percentage of analog potentiometer input correlating to a 0 to 10 V dc analog input signal digitized value.

Differential versus Single-Ended Analog Inputs

Physically connecting analog input signals to an analog input module may be different from using a discrete input module. Analog input modules are classified as either single-ended or differential.

Single-ended inputs to an analog input module have all input commons tied together. Differential inputs each have their own individual input and corresponding common. As a result, a differential connected module will have half as many channels as a single-ended configuration. Figure 7-44 illustrates a typical single-ended analog input interface. Note that shielded cable is used to connect to the input point from the analog transmitter. Shielded cable is used to help keep field noise out of the input signal. The shield should be connected to the chassis ground lug only. The analog source end of the cable should be taped only to insulate the shield from any electrical connection.

Single-Ended versus Differential Inputs

Although there are more types of input channels available with single-ended inputs, they are subject to more potential problems with noise entering the channel, which causes inconsistent input data and ground currents. A converted differential input signal is the difference between the channel's positive input and the channel's negative input. Differential input channels have two input connections per channel. If an equal amount

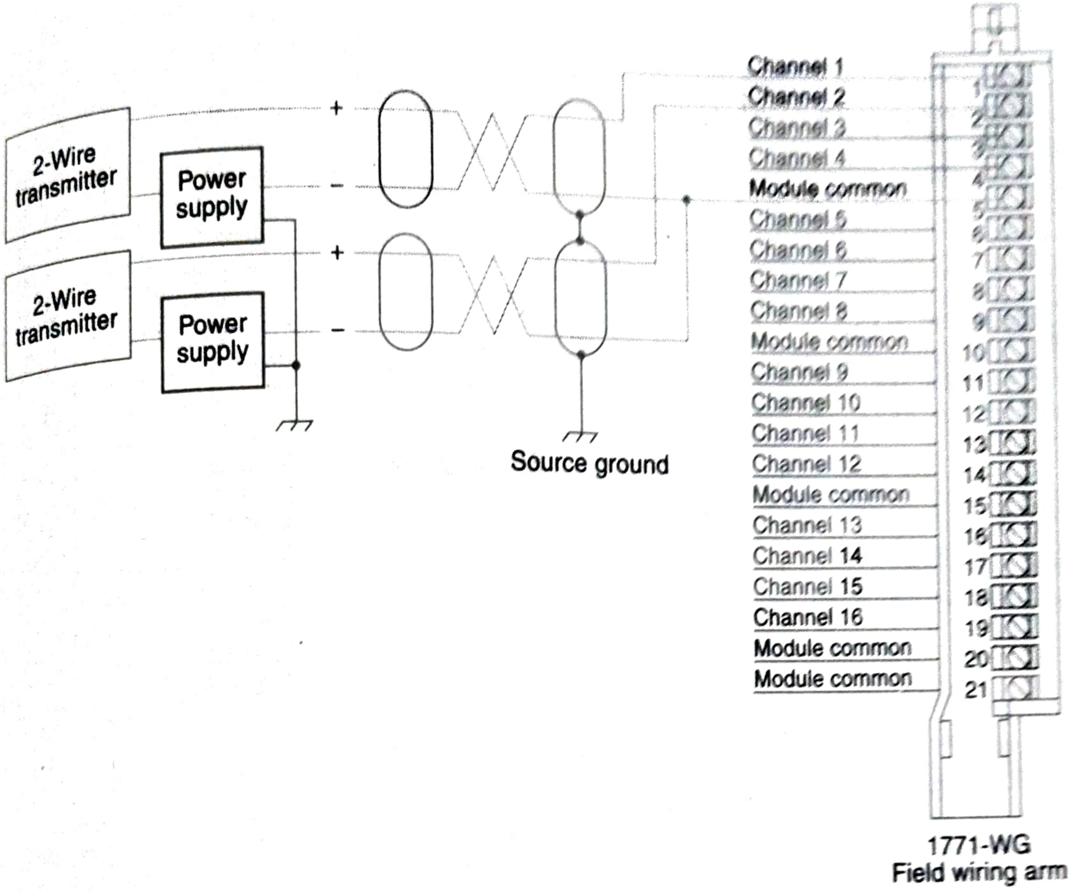

Figure 7-44 Single-ended analog input connections from field devices. (Used with permission of Rockwell Automation, Inc.)

of noise is picked up in the input wiring, the module will look for the difference between the two input lines. With a differential input, noise on both input channel inputs will theoretically be filtered out, leaving only the actual input signal.

Figure 7-45 illustrates differential input connections to an Allen-Bradley PLC 5 analog input module.

This section has only introduced you to the basic principles of analog input modules and their interfaces to a PLC input module. The next section will introduce some input modules that have been developed to allow the PLC to interface in special application situations. These modules provide an interface only for the application for which they were developed. These special modules are called specialty modules.

SPECIALTY MODULES

Specialty modules fall into the category of smart modules. A smart module contains its own microprocessor. Specialty modules are designed to provide a specific function. This section will provide a quick overview of some of the more popular smart input and output modules.

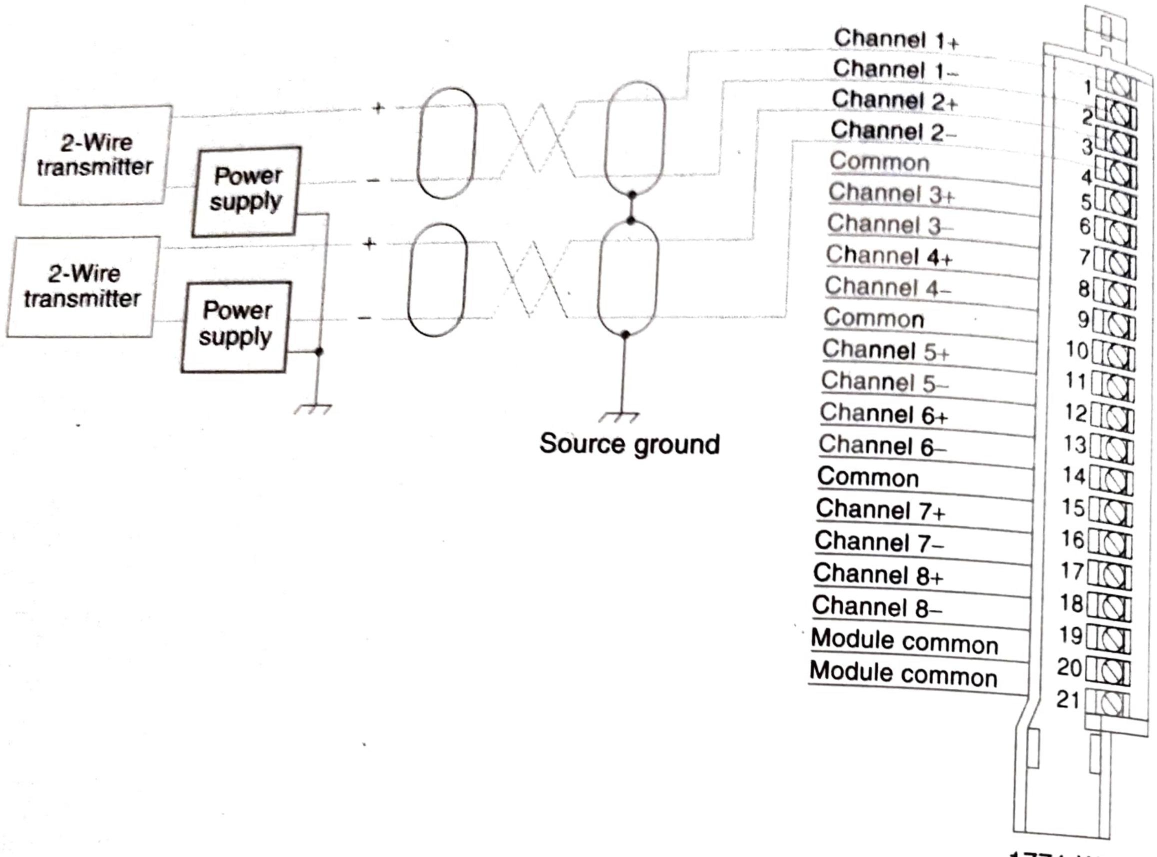

Figure 7-45 Differential analog input connections from field devices to an Allen-Bradley PLC 5, 1771 IFE analog input module. (Used with permission of Rockwell Automation, Inc.)

BASIC Module

A BASIC module is a specialized module that allows the PLC to interface to serial peripheral devices. BASIC modules usually reside in the local chassis, close to the CPU. The operator develops a separate BASIC language program, which is downloaded into the BASIC module. Typically, a program written in the BASIC programming language, or some variation of it, is placed into the BASIC module's memory. Different manufacturers may have their own variations of the BASIC programming language. To receive maximum performance, you must use that manufacturer's software when programming the BASIC module. BASIC modules usually have a programming port that is compatible with RS-232C or RS-422 communication standards. The module will have at least one serial port to interface from the PLC's CPU to printers, ASCII terminals, bar code readers, and asynchronous modems. The BASIC module can also perform computational tasks, thus relieving the burden of the CPU.

Communication Modules

ASCII I/O Modules. ASCII I/O modules allow the interfacing of bar code readers, meters, printers, and data terminals to a PLC. ASCII modules, which accept only valid ASCII data, are not used as extensively as they once were. Today, the RS-232 module is the module of choice in many applications.

RS-232C Interface Modules. Communication modules are available that reside in a PLC chassis and enable you to connect a PLC to telephone lines using a modem. PLCs connected to phone lines allow central control room operators to examine ladder programs to modify or edit program operation at remote PLC sites. Today many remote oil, gas, and wastewater applications are unmanned. Remote access by way of phone lines saves maintenance personnel from driving to remote sites each time a PLC encounters a problem or a program change is necessary.

High-Speed Encoder Input Modules

When input pulses come in faster than a discrete input module can handle them, a high-speed input module is used. High-speed counters are also used to interface encoders to a PLC.

Remote I/O Subscanners

When you need an I/O chassis remotely mounted from the base PLC, some PLC systems require a remote I/O subscanner. Simply put, a subscanner resides in the base CPU chassis and relieves the CPU from the burden of scanning the I/O. A subscanner scans the remote I/O chassis and the respective I/O points. After the subscanner has scanned all remote I/O points, their I/O status is stored in a built-in buffer (storage area). At the appointed time in the CPU's scan, the CPU will read the I/O status data stored in the subscanner's buffer.

Resistance Temperature Detector (RTD) Input Modules

A resistance temperature detector (RTD) input module interfaces a PLC to RTD temperature-sensing elements and other types of resistance input devices such as potentiometers. The RTD input module converts analog input signals from a potentiometer or RTD into input signals understood by the PLC. These values are stored in the PLC input table.

Stepper Motor Control Modules

A stepper module is an intelligent module that resides in a PLC chassis and provides a digital output pulse train for microstepping stepper motor applications.

Thermocouple/Millivolt Input Module

The thermocouple/millivolt input module converts inputs from various thermocouple or millivolt devices into values that can be input and stored into PLC data tables. This module greatly enhances the flexibility of a PLC system by interfacing thermocouples, thus eliminating expensive thermocouple transmitters. Using an RTD module, PLCs can then be used for interface applications requiring temperature and measurement control.

SUMMARY

Early programmable controllers were strictly limited to discrete inputs. Today's programmable controllers are much more sophisticated, thanks to vast advances in microprocessor technology. The increase in sophistication of these programmable controller devices mandates increased abilities and understanding from those individuals who will be applying this new technology to current and new applications. Today's programmable controller can be applied to practically any control problem due to its complete range of discrete, analog, and specialty interface control abilities.

There are four categories of input modules: input modules, combination input and output modules, analog current or voltage input modules, and combination analog input and output modules.

Input modules typically are available with 4, 8, 16, 24, or 32 points. Discrete input modules interface to AC, DC, and +5 DC TTL discrete voltage signals. Analog input modules interface to varying input signals such as temperature and pressure. Analog input modules are available as 2, 4, 8, or 16 channels.

Specialty modules are designed to provide a specific interface solution. Specialty modules give the PLC added functionality to interface modems, high-speed inputs, encoders, stepper motors, thermocouples, and RTDs, to name a few.

In this chapter we explored discrete and analog input modules and how these modules interface signals to real-world devices and the CPU. We also introduced selected specialty modules and described how they enhance a PLC's functionality.

REVIEW QUESTIONS

1. Input modules provide an interface between
   A. Input modules and the CPU
   B. Field equipment and the CPU
   C. Output modules and field devices
   D. The CPU and output modules
2. Discrete I/O input modules accept signals from field devices that are:
   A. Analog devices
   B. Digital devices
   C. Two-state devices
   D. Discrete devices
   E. A , B, and C are correct.
   F. B, C, and D are correct.
3. Name three analog inputs.
4. Name five discrete inputs.

5. What are the five main sections of an AC input module?
6. What is the purpose of the bridge rectifier section of an AC input module?
7. A discrete input signal is considered valid if the signal:
   A. Is a two-state signal
   B. Is successfully changed from AC to DC through the bridge rectifier
   C. Is accepted and passed through the threshold detector
   D. Is successfully debounced
   E. For an AC signal, if it is between 80 and 132 VAC
   F. All of the above
8. Electrical isolation is provided so that there is no physical electrical connection between the CPU and field devices. This isolation is usually accomplished by ________.
9. We introduced thumbwheel switches in Chapter 2. Thumbwheels provide input to the PLC in what format?
10. What are typical applications where we would employ thumbwheel switches?
11. How many wires would be connected to an input module from the three-digit thumbwheel?
12. If we wanted to interface three groups of three-digit thumbwheels to our PLC, how many wires would we have to hook up?
13. Thumbwheels are a state-of-the-art (and very popular) interface medium for modern PLCs—true or false? Explain your answer.
14. Illustrate how you would connect two 115 VAC input devices to an input module. Assume there are different phases on each line.
15. Illustrate a block diagram of a typical AC input module. Identify the blocks.
16. Explain where you would use an isolated I/O module.
17. A sinking input module is:
    A. Always the same no matter who manufactured it
    B. Different among different manufacturers
18. An NPN inductive proximity sensor would interface to what part of an Allen-Bradley SLC 500?
    A. Sinking input module
    B. Sourcing input module
19. A sourcing input module is:
    A. Always the same no matter who manufactured it
    B. Different among different manufacturers
20. A PNP inductive proximity sensor would interface to what part of an Allen-Bradley SLC 500?
    A. Sinking input module
    B. Sourcing input module