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 VDC
48 VAC	48 VDC
120 VAC	10–60 VDC
240 VAC	120 VDC
Nonvoltage	230 VDC
120 Volts Isolated	Sink/Source 5–50 VDC
240 Volts Isolated	5 VDC TTL level
24 VAC/DC	5/12 VDC 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 VDC 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 comprised of three parts: power file conversion, isolation, and logic, as illustrated in Figure 7-4.

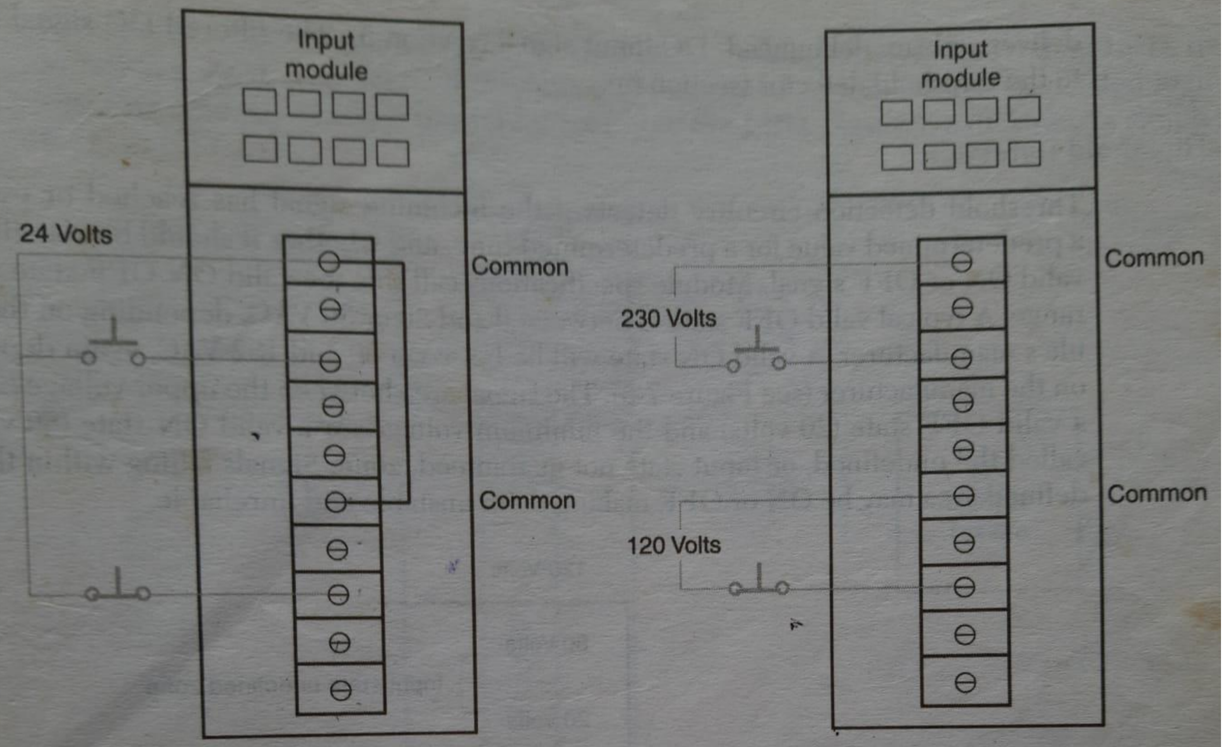

Figure 7-3 Typical wiring of input signals into a 120-VAC eight-point input module.

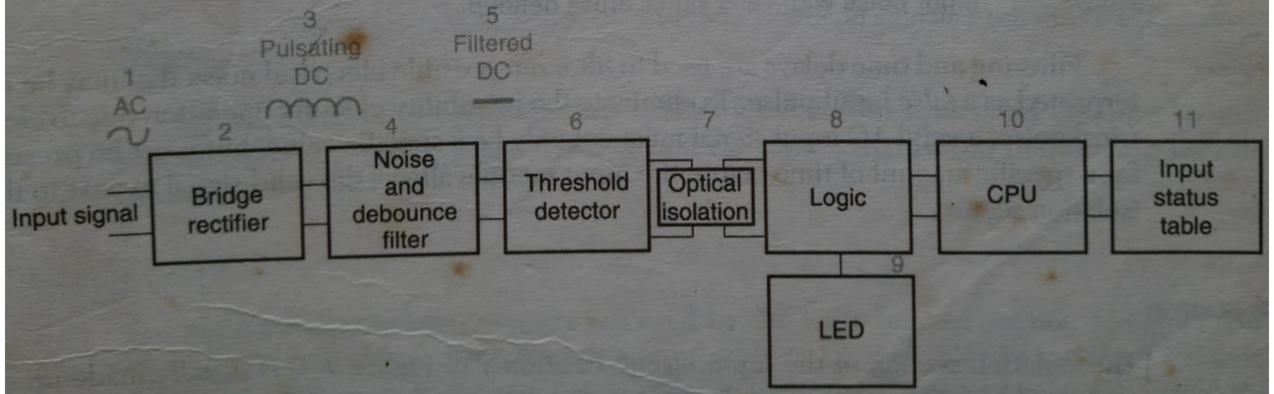

Figure 7-4 Block diagram of a typical AC input circuit.

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.

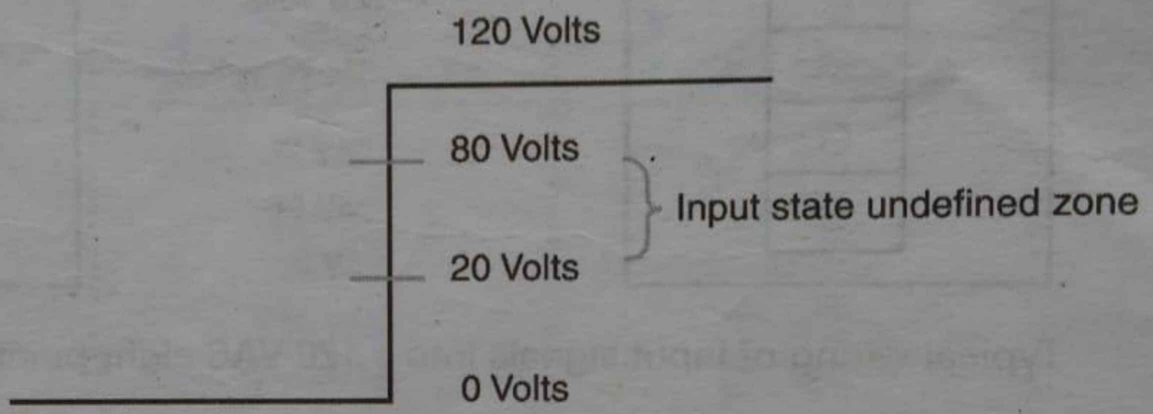

Figure 7-5 Input pulse with valid signal areas defined.

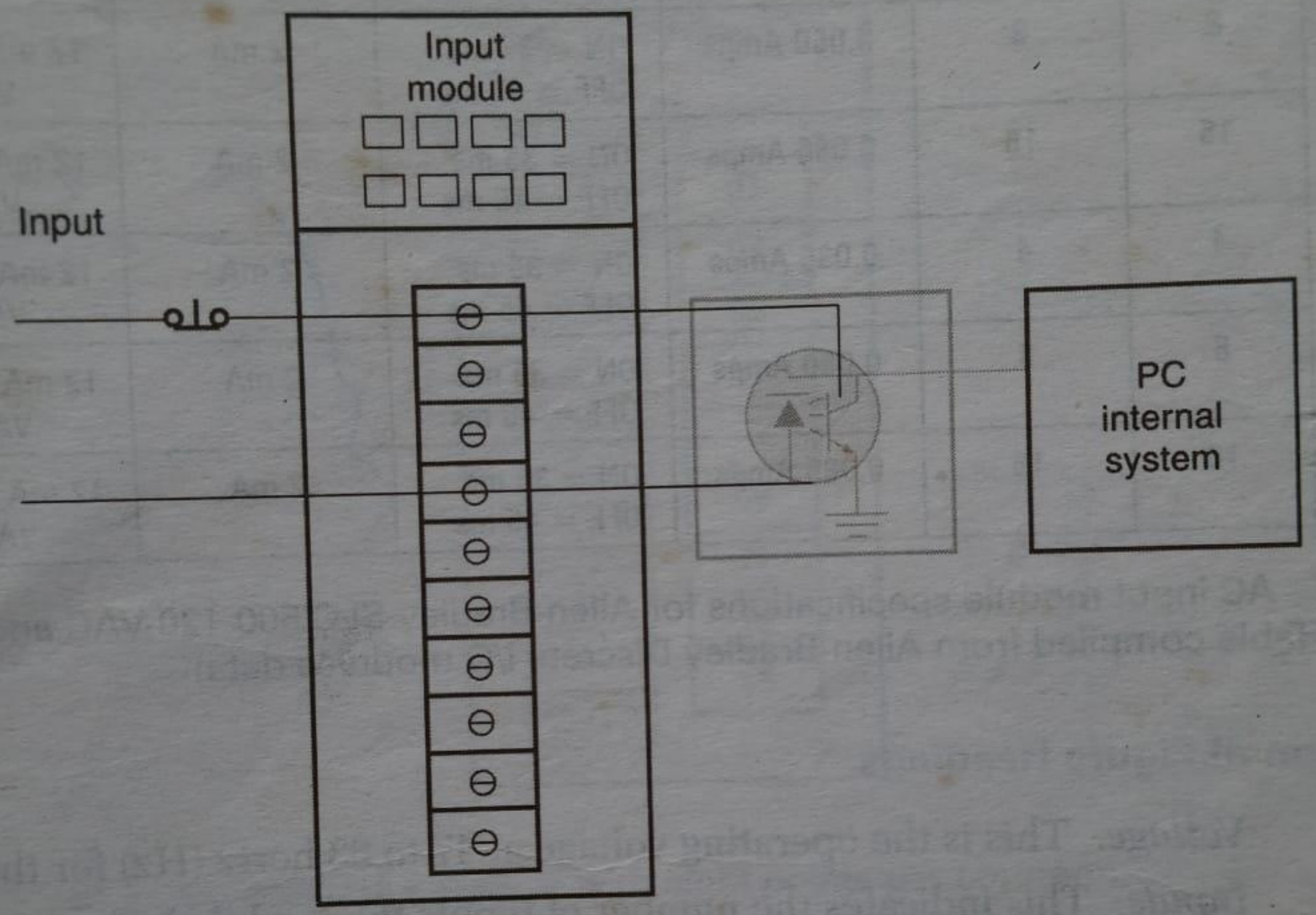

Figure 7-6 Optical isolator to isolate high-voltage incoming signals from the CPU's lower voltage levels.

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.

Voltage	Inputs	Points per Common	Backplane Current Draw at 5 VDC	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)

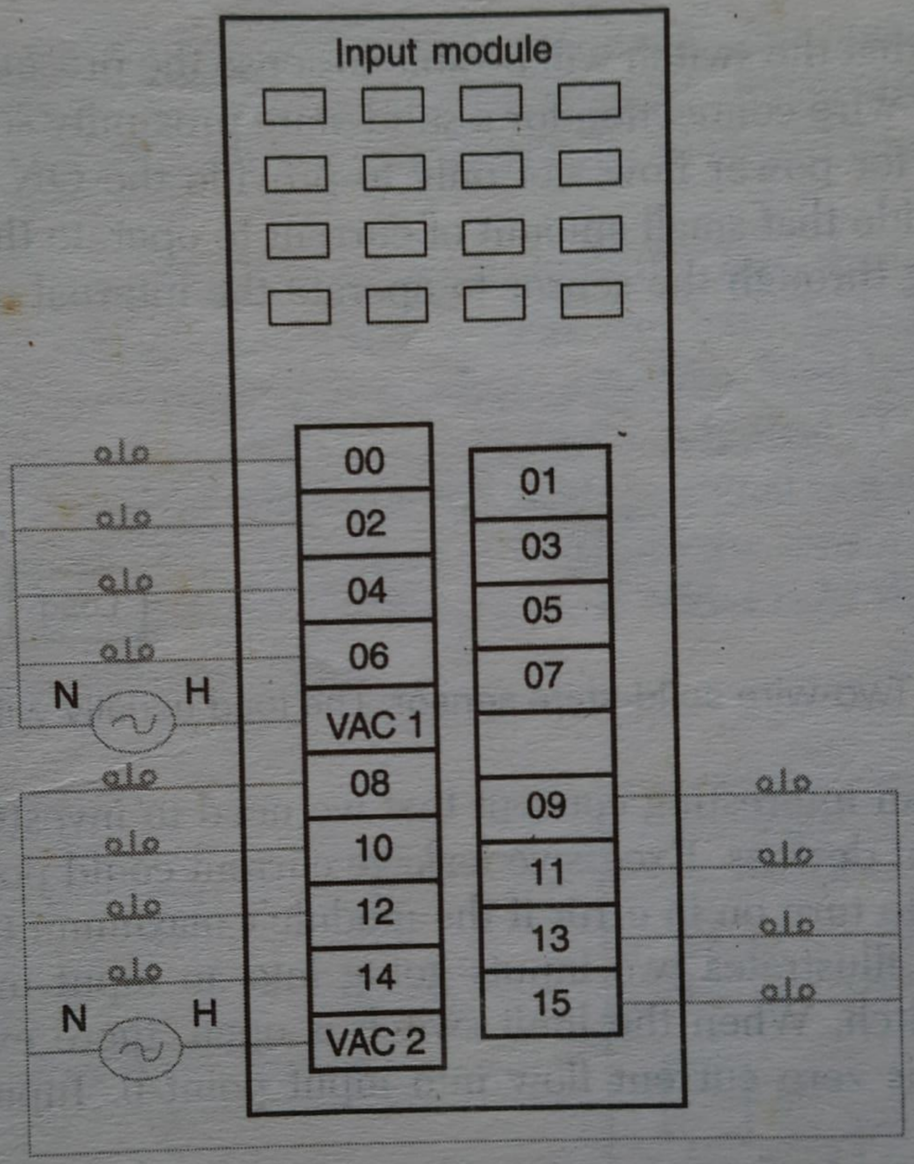

Figure 7-8 Sixteen-point input module with eight points per common.

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."

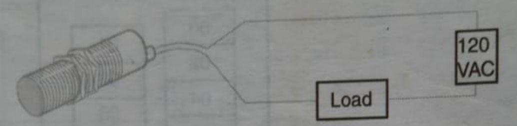

Figure 7-9 Two-wire solid-state sensor. The load usually will be a PLC input module.

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

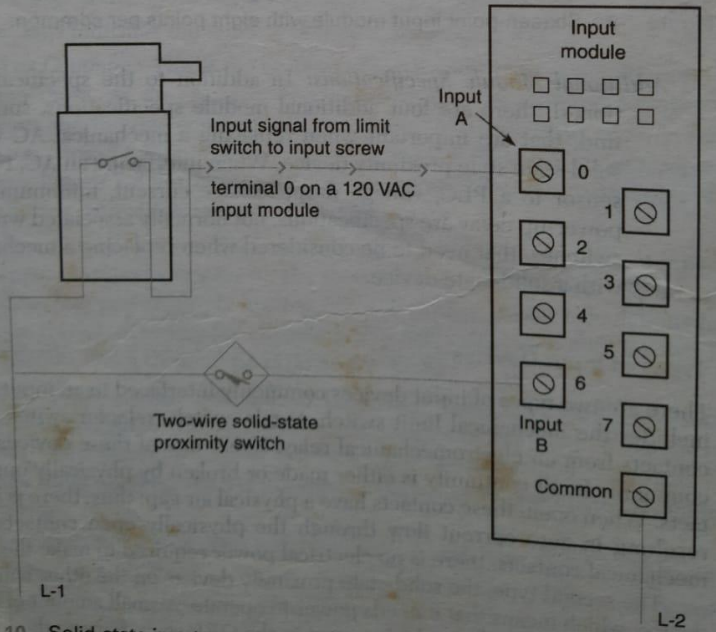

Figure 7-10 Solid-state input versus a mechanical switch as input to an input module.

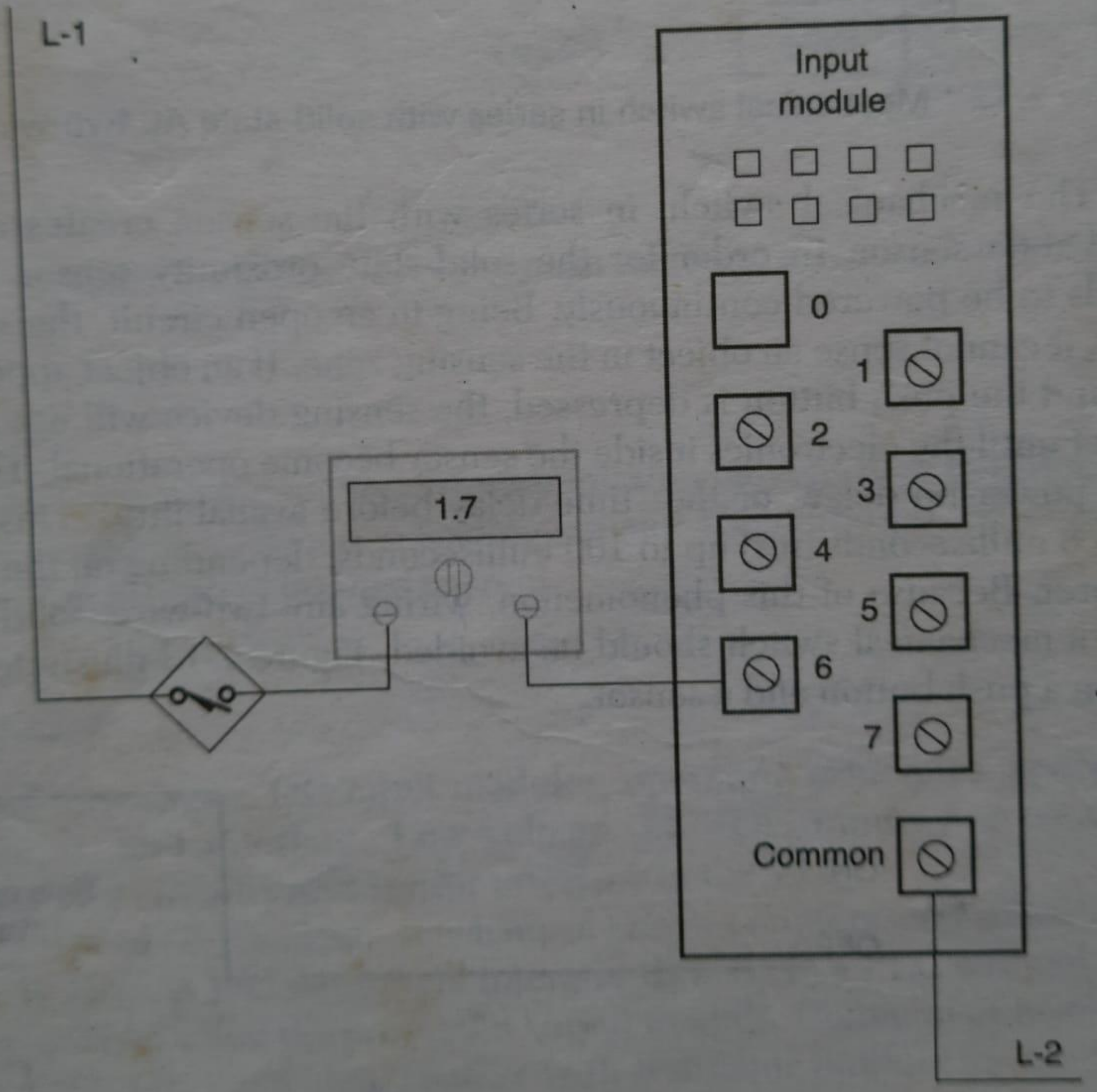

Figure 7-11 Amp meter showing leakage current in a two-wire DC sensor input circuit.

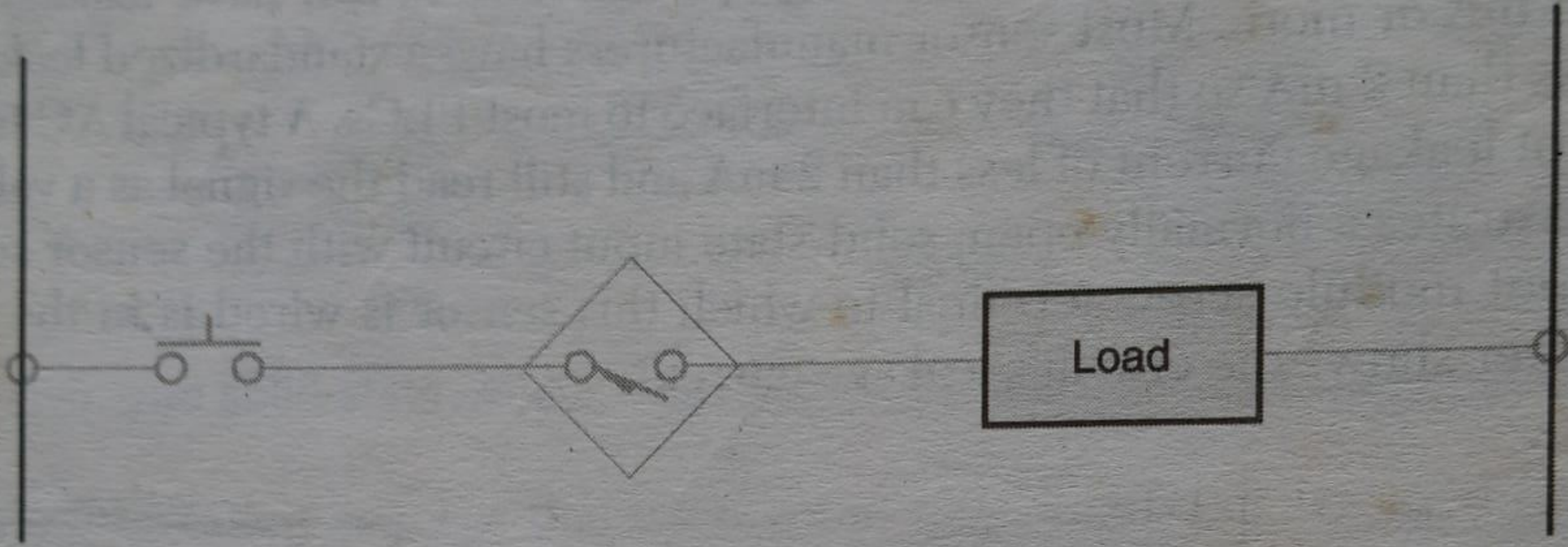

Figure 7-12 Mechanical switch in series with solid-state AC two-wire sensor.

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.

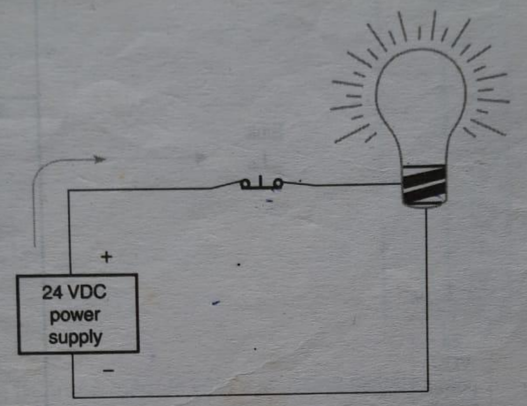

Figure 7-16 Sinking and sourcing DC circuit. The switch is the source of current that the light sinks to ground.

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.

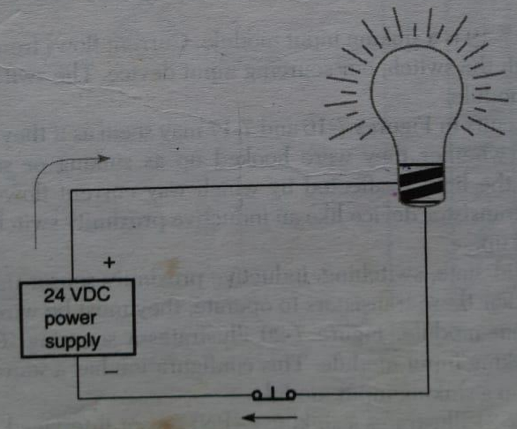

Figure 7-17 Sinking and sourcing DC circuit. The light is the source of current that the switch sinks to ground.

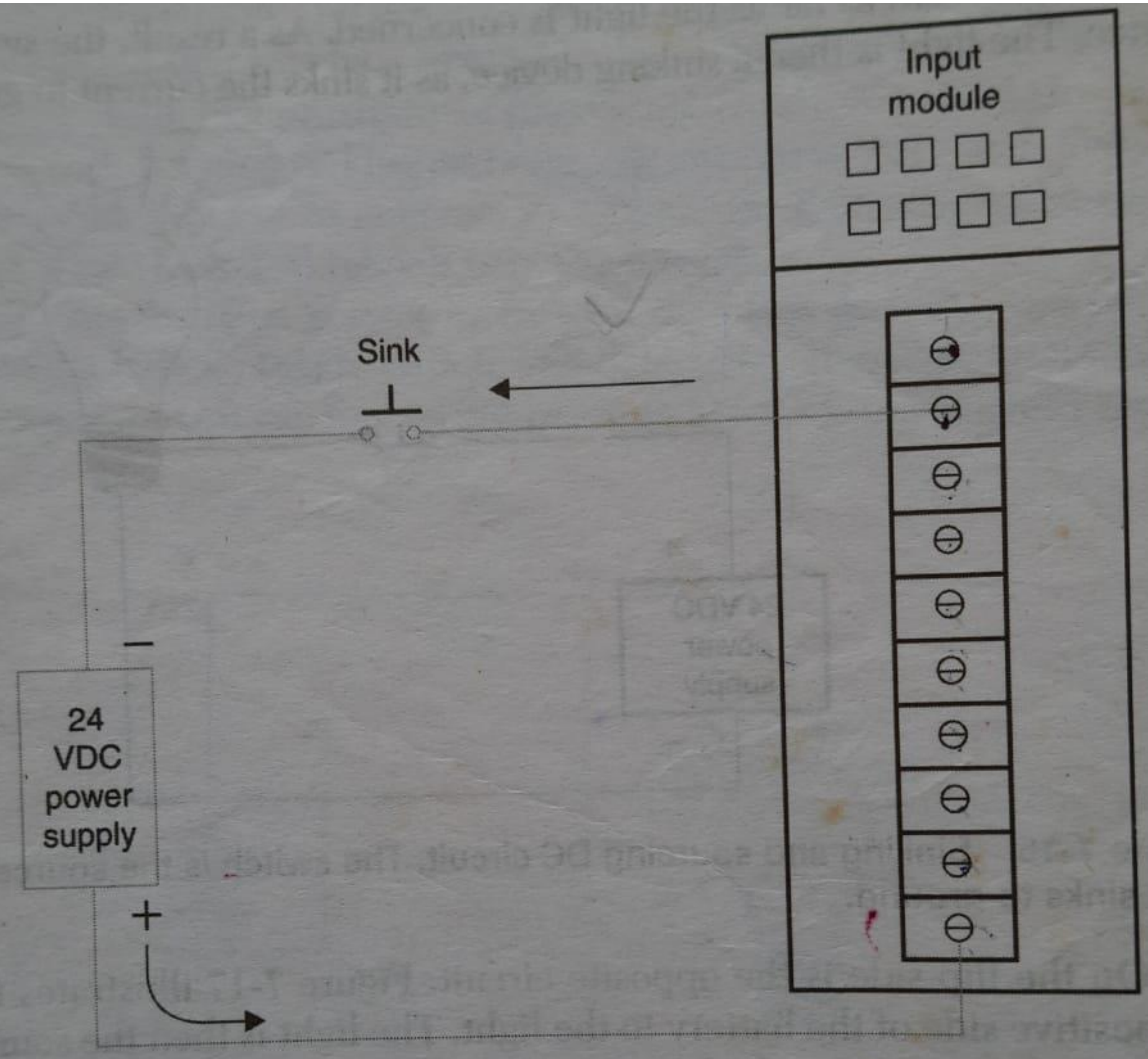

Figure 7-18 Sourcing DC input module with a sinking switch.

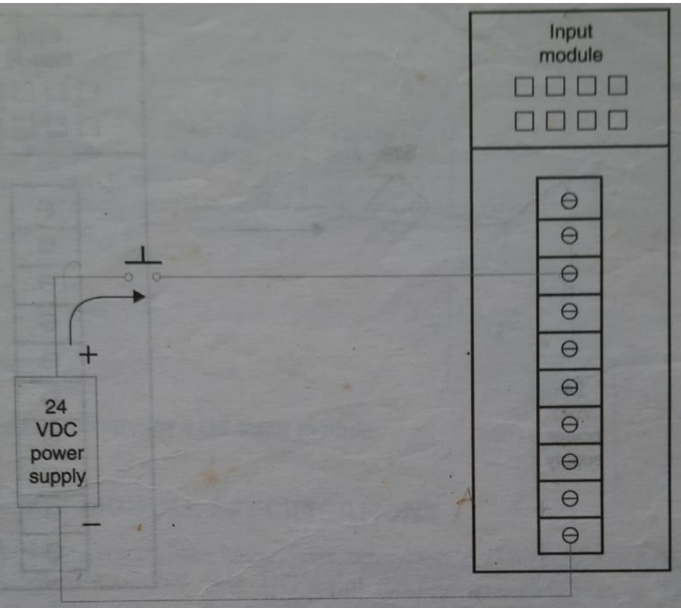

Figure 7-19 Sinking DC input module with a sourcing switch.

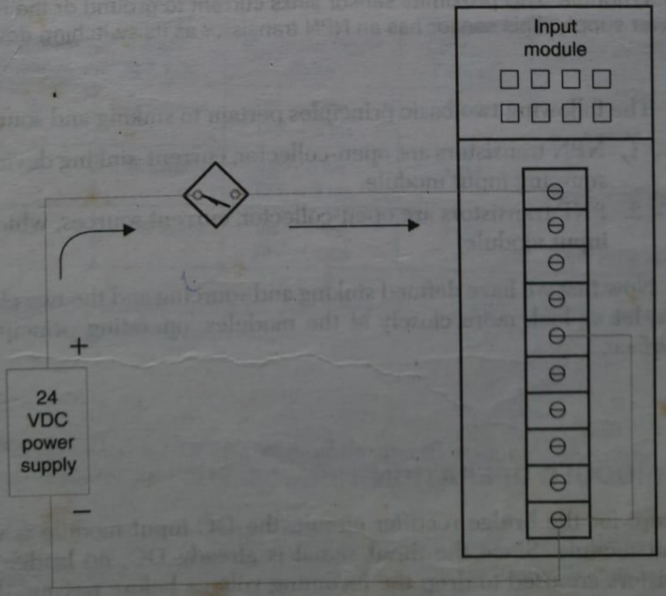

Figure 7-20 Sourcing two-wire inductive proximity sensor interfaced to a sinking 24-VDC input module.

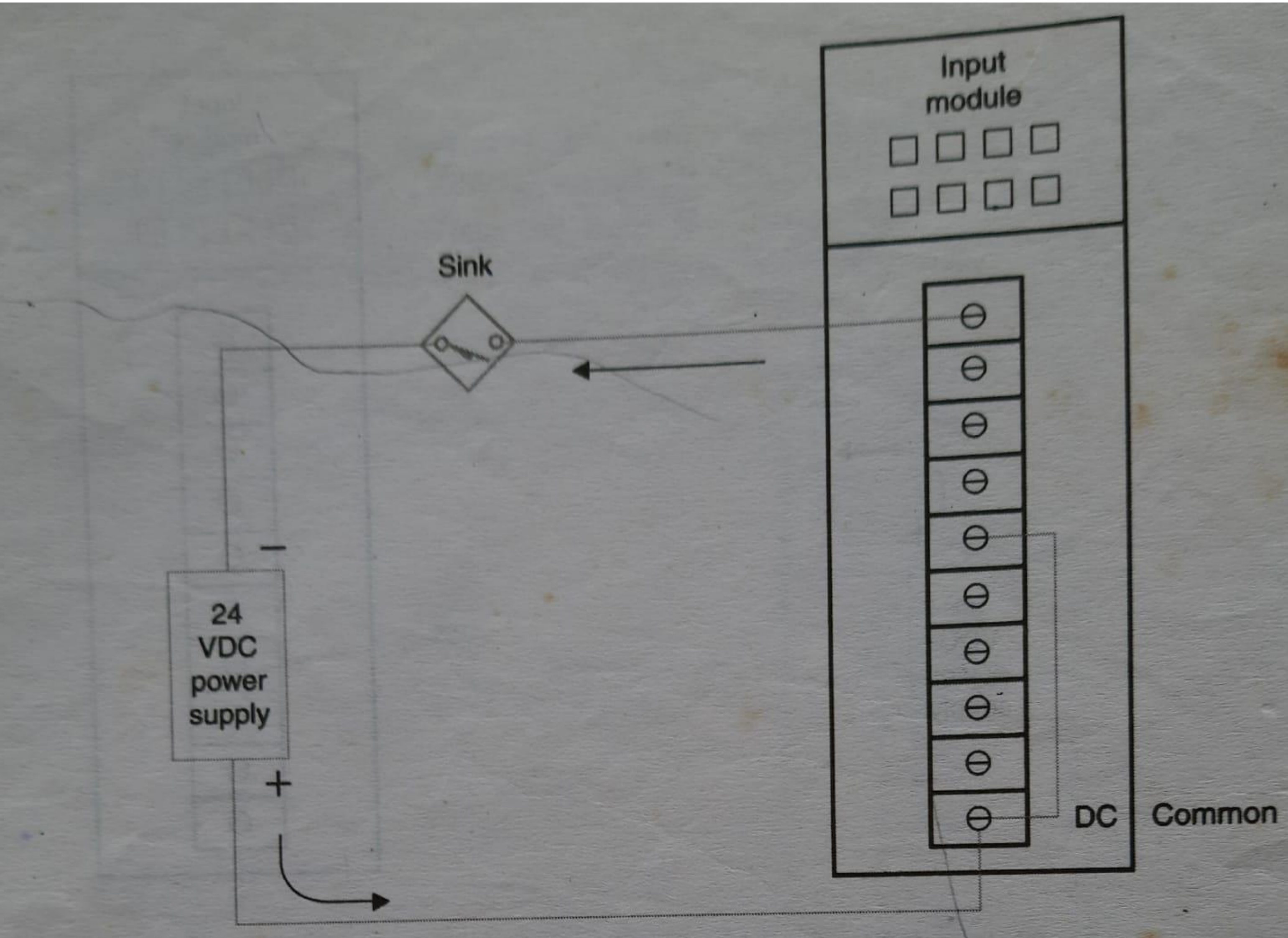

Figure 7-21 Sinking two-wire inductive proximity sensor interfaced to a sourcing 24-VDC input module. This proximity sensor sinks current to ground or the negative side of the power supply. This sensor has an NPN transistor as its switching device.

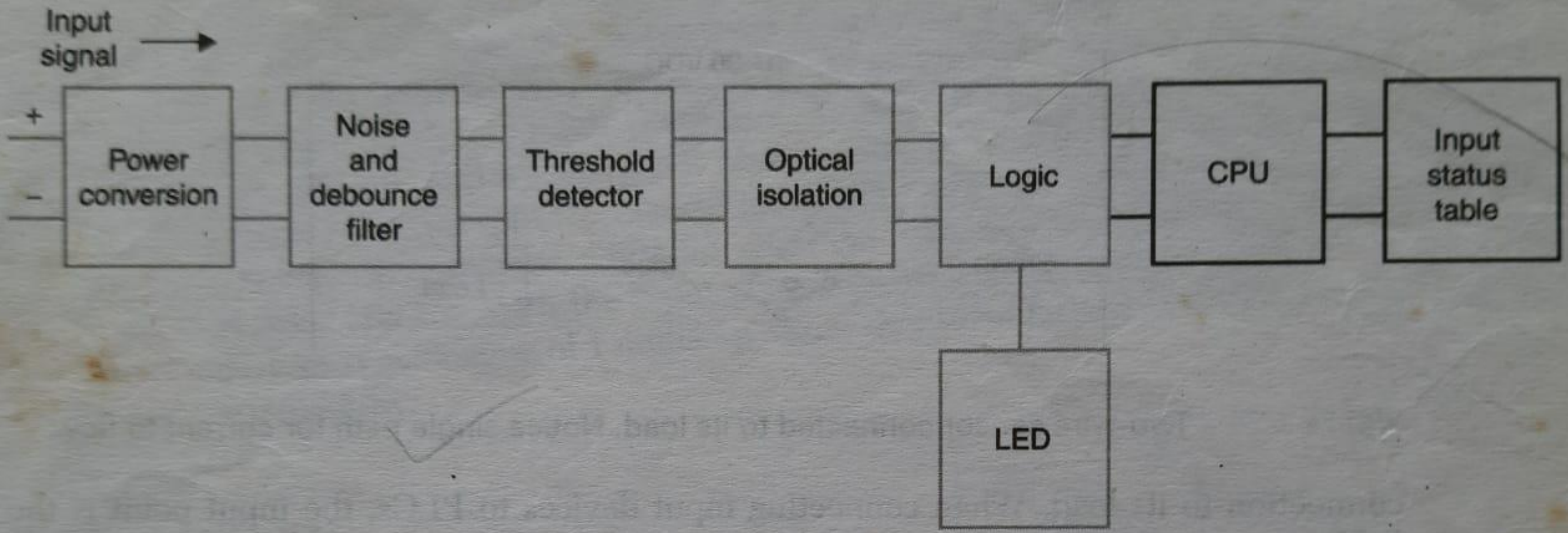

Figure 7-22 Simplified circuitry for a DC input module.

SOLID-STATE SENSOR INTERFACE TO DC INPUT MODULES

We are going to interface selected two- and three-wire inductive proximity sensors to different 24 VDC 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 CATALOG NUMBERS		
Module Specification	**1746-IA16**	**1746-IB8**	**1746-IV8**
Operating Voltage	85–132 VAC	10–30 VDC Sink	10–30 VDC Source
Number of Inputs	16	8	8
Points per Common	16	8	8
Backplane Current Draw at 5 VDC	.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 VDC	5 VDC
Nominal Input Current	12 mA at 120 VAC	8 mA at 24 VDC	8 mA at 24 VDC
Maximum Inrush Current	.8 A	NA	NA

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

Sensor Specifications	SENSOR CATALOG NUMBERS		
	872C- D8NE 18-A2	871TM- DH4NE-12-A2	871TM- DH8NE-18-A2
Operating Voltage	10–55 VDC Source	10–30 VDC Source	10–30 VDC 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	60 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 VDC.
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.

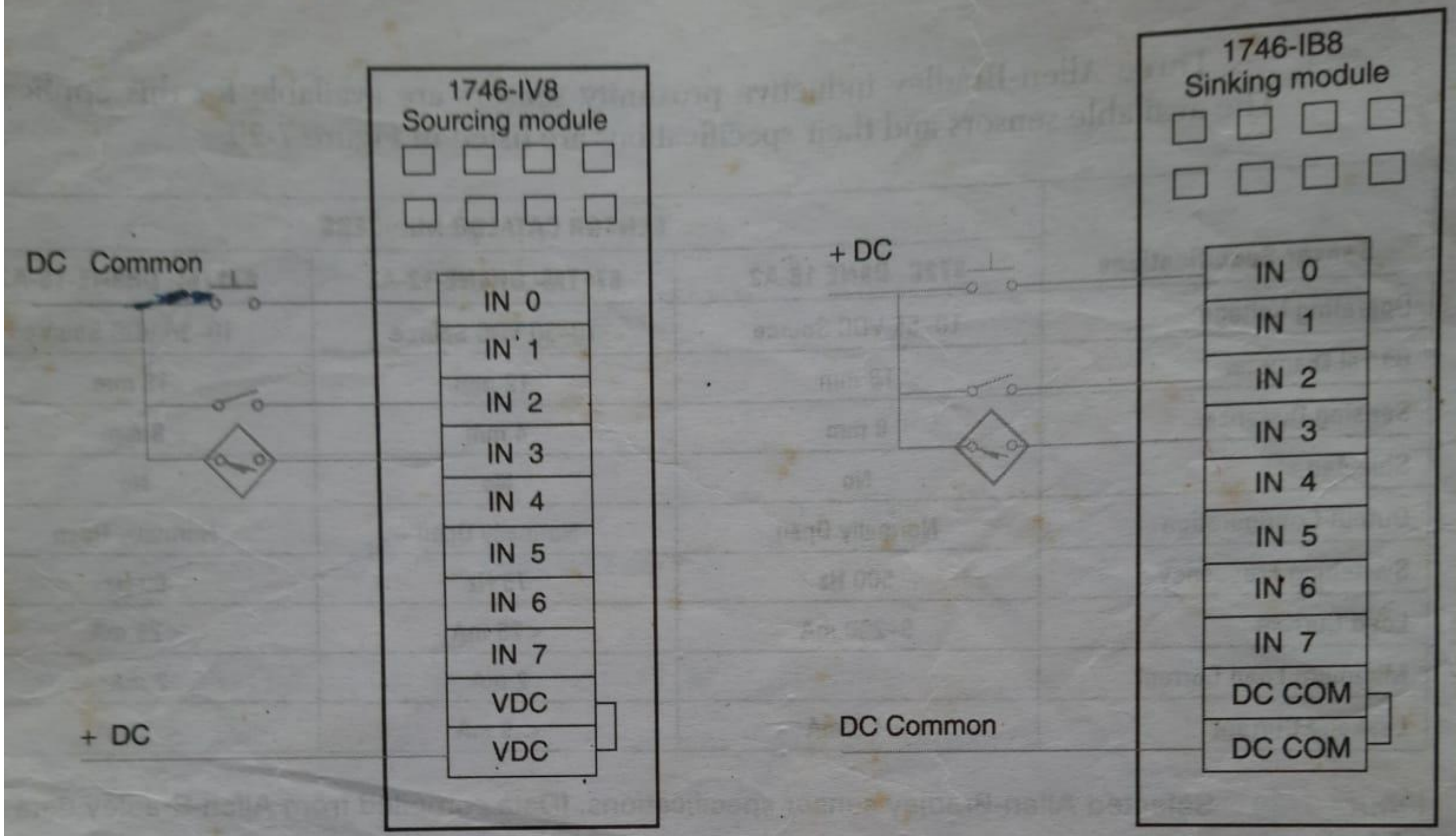

Figure 7-30 Wiring diagrams for the Allen-Bradley SLC 500 1746-IV8 and 1746-IB8. (Courtesy of Allen-Bradley, a Rockwell Automation business)

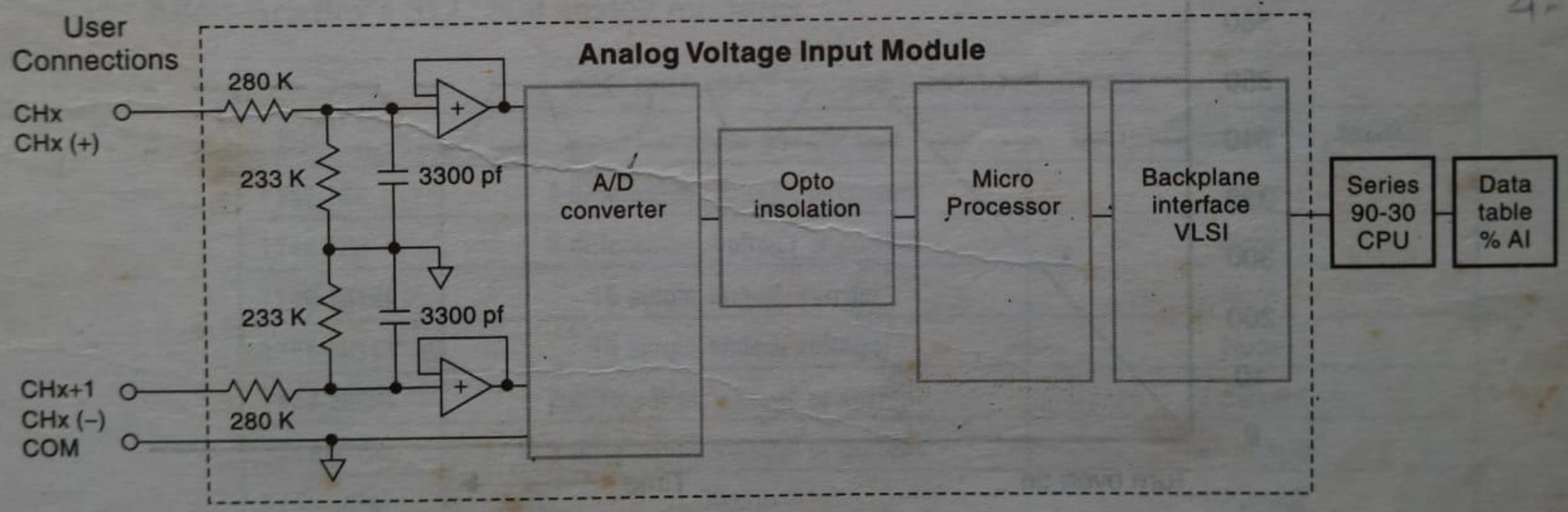

Figure 7-32 Analog voltage input module block diagram for a General Electric IC693ALG222 module. (Courtesy of GE Fanuc Automation)

Input modules come in three configurations: all inputs, all outputs, and combination 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."

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 2, 3, and 4 would be represented in the input status table as illustrated in Figure 7-37.

																I:2
																I:3
																I:4

Figure 7-37 Input status table representation for input modules in slots 2, 3, and 4.

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 word zero, data can be stored in word 1, word 2, word 3, and all the way up to word 255, as illustrated in Figure 7-38.

																I:2.0
																I:3.0
																I:3.1
																I:3.2
																I:3.3
																↓
																I:3.255
																I:4.0

Figure 7-38 Input status table reflecting words available for slot three.

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.

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.

																I:2.0
																I:3.0
																I:3.1
																I:3.2
																I:3.3
																I:4.0

Figure 7-39 Input status table reflecting words available for slot three.

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. (Courtesy of Allen-Bradley, a Rockwell Automation business)

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. (Courtesy of Allen-Bradley, a Rockwell Automation business)

Differential Versus Single ended Analog Inputs

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 only be taped in order 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 of noise is picked up in the input wiring, the module will look for the difference between

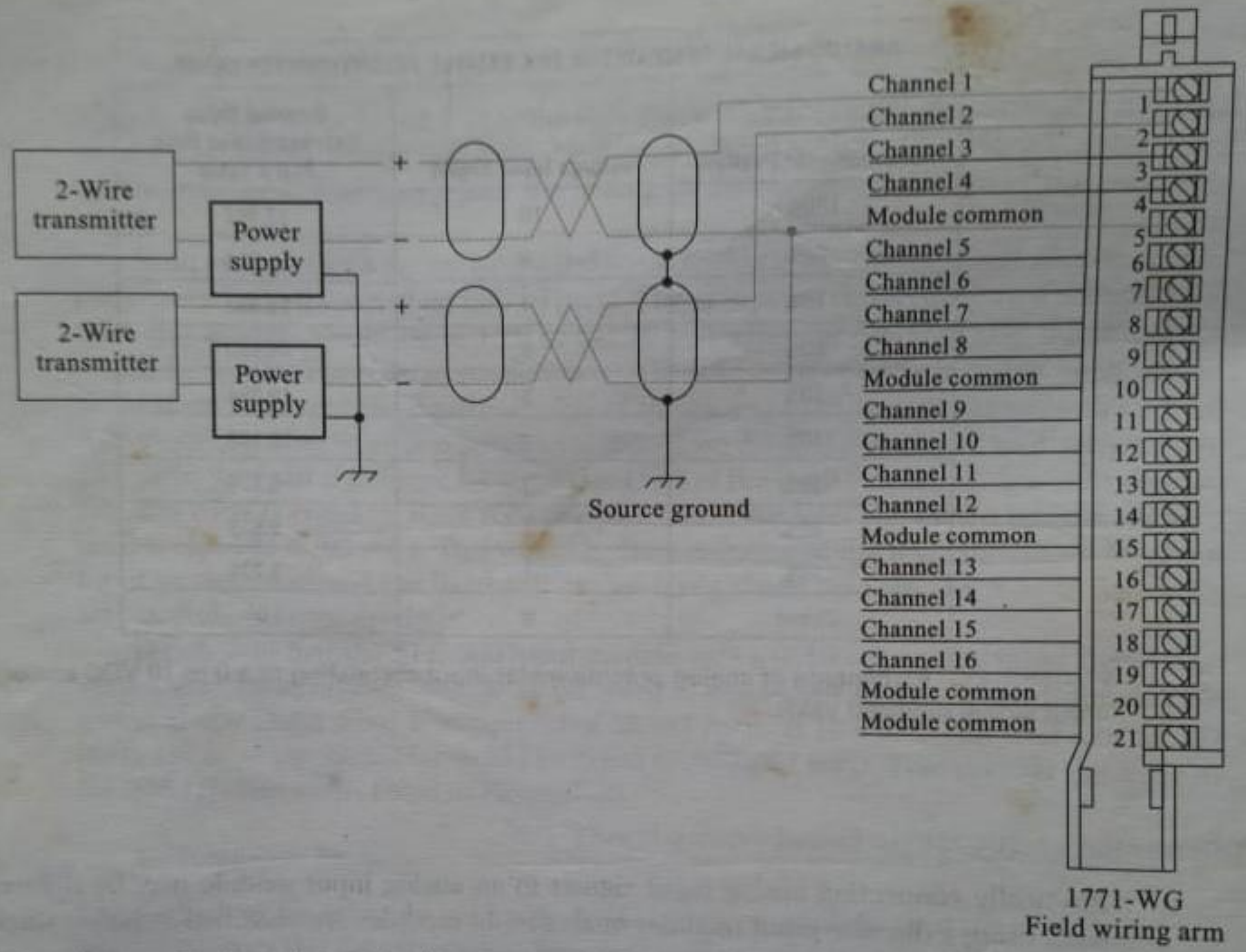

Figure 7-44 Single-ended analog input connections from field devices. (Courtesy of Allen-Bradley, a Rockwell Automation business)

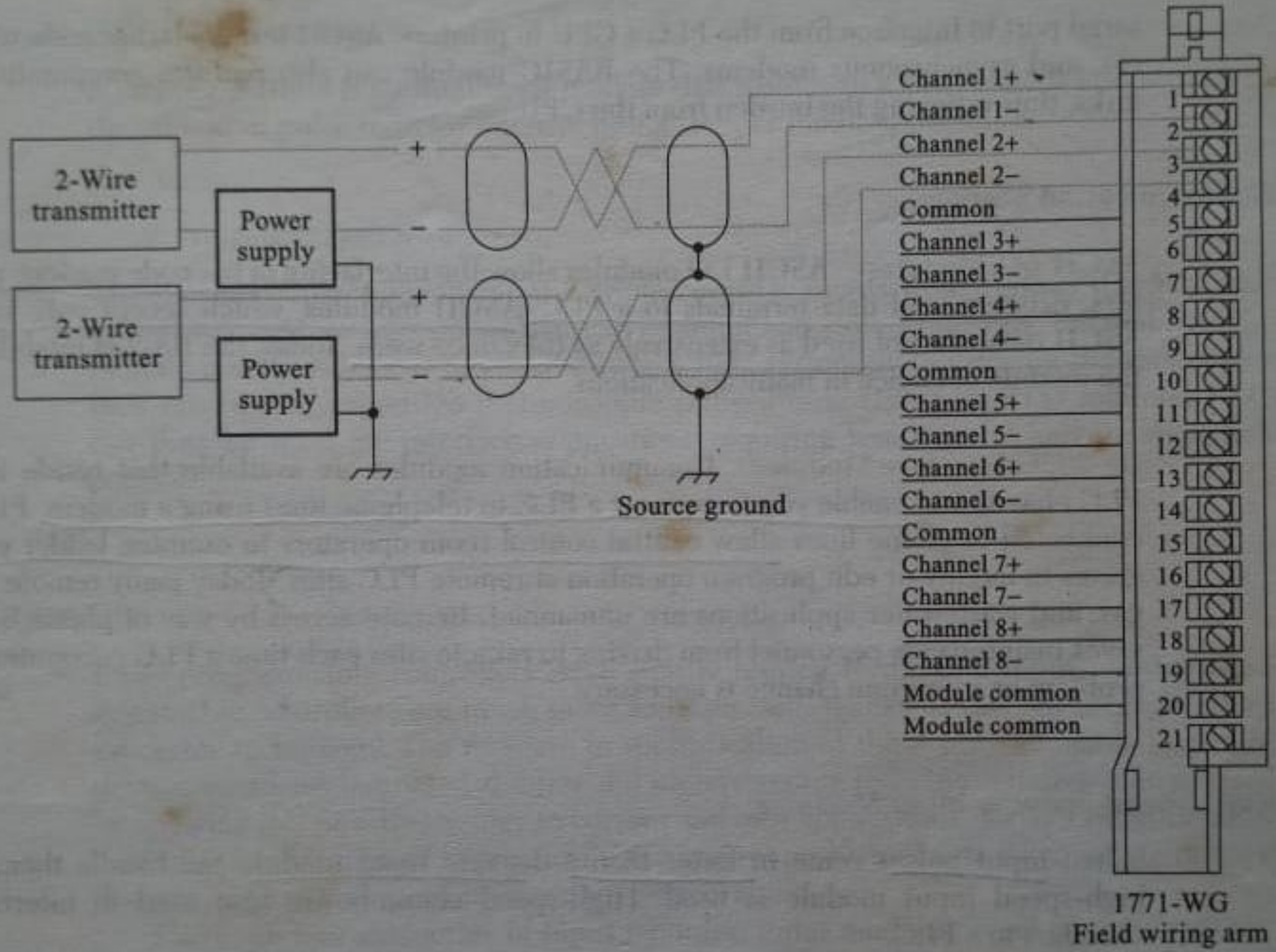

Figure 7-45 Differential analog input connections from field devices to an Allen-Bradley PLC 5, 1771 IFE analog input module. (Courtesy of Allen-Bradley, a Rockwell Automation business)

Specialty Module

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 variation 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 from 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 thus 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 like 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.