Almamoun University collage

Power electrical Engineering

المسيطرات الرقمية والمعالج الدقيق

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Lecture 5

2.3 Analog I/O Modules

Earlier PLCs were limited to discrete or digital I/O interfaces, which allowed only on/off-type devices to be connected. This limitation meant that the PLC could have only partial control of many process applications. Today, however, a complete range of both discrete and analog interfaces are available that will allow controllers to be applied to practically any type of control process. Discrete devices are inputs and outputs that have only two states: on and off. In comparison, analog devices represent physical quantities that can have an infinite number of values. Typical analog inputs and outputs vary from 0 to 20 milliamps, 4 to 20 milliamps, or 0 to 10 volts. Figure 2-22 illustrates how PLC analog input and output modules are used in measuring and displaying the level of fluid in a tank. The analog input interface module contains the circuitry necessary to accept an analog voltage or current signal from the level transmitter fi eld device. This input is converted from an analog to a digital value for use by the processor. The circuitry of the analog output module accepts the digital value from the processor and converts it back to an analog signal that drives the field tank level meter.

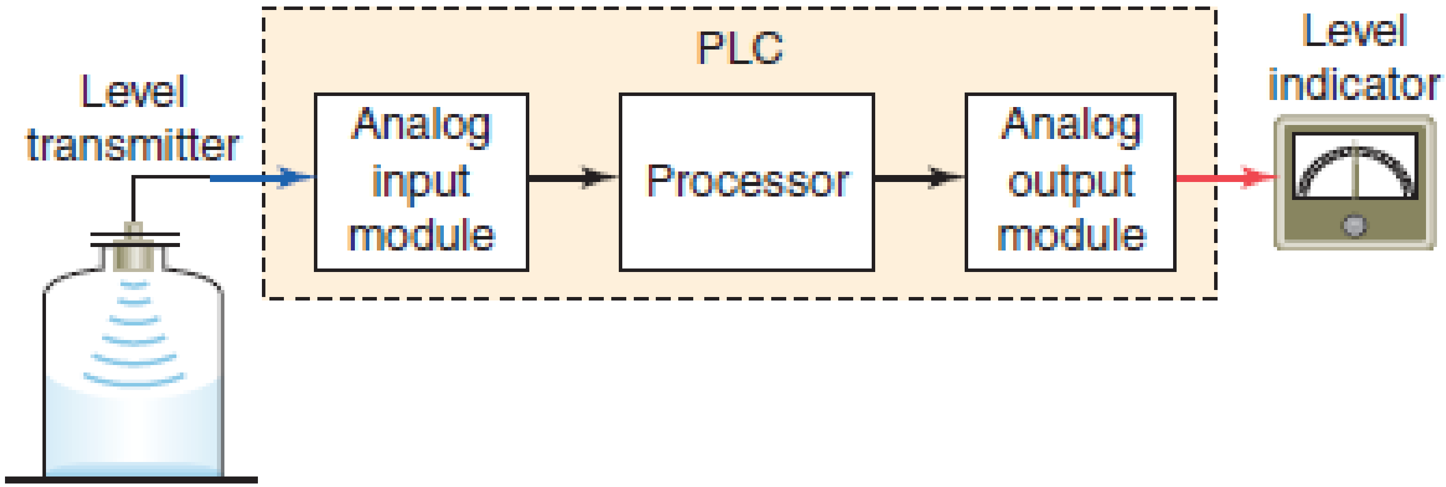

Figure 2-22 Analog input and output to a PLC.

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

Figure 2-23 illustrates an example of a voltage sensing input analog module used to measure temperature. The connection diagram applies to an Allen-Bradley Micro-Logic 4-channel analog thermocouple input module. A varying DC voltage in the low millivolt range, proportional to the temperature being monitored, is produced by the thermocouple. This voltage is amplified and digitized by the analog input module and then sent to the processor on command from a program instruction. Because of the low voltage level of the input signal, a twisted shielded pair cable is used in wiring the circuit to reduce unwanted electrical noise signals that can be induced in the conductors from other wiring. When using an ungrounded thermocouple, the shield must be connected to ground at the module end. To obtain accurate readings from each of the channels, the temperature between the thermocouple wire and the input channel must be compensated for. A cold junction compensating (CJC) thermistor is integrated in the terminal block for this purpose.

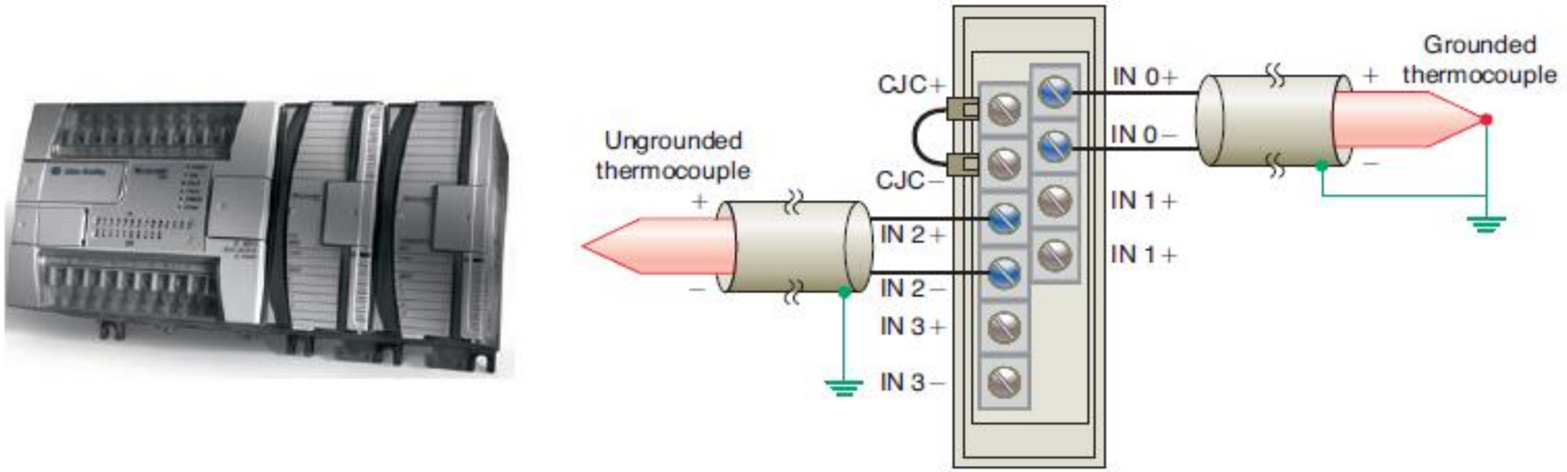

Figure 2-23 MicroLogix 4-channel analog thermocouple input module.
Source: Image Used with Permission of Rockwell Automation, Inc.

The transition of an analog signal to digital values is accomplished by an analog-to-digital (A/D) converter, the main element of the analog input module. Analog voltage input modules are available in two types: unipolar and bipolar. *Unipolar* modules can accept an input signal that varies in the positive direction only. For example, if the fi eld 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 fi eld device outputs 210 V to 110 V a bipolar module would be used. The *resolution* of an analog input channel refers to the smallest change in input signal value that can be sensed and is based on the number of bits used in the digital representation. Analog input modules must produce a range of digital values between a maximum and minimum value to represent the analog signal over its entire span. Typical specifications are as follows:

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

When connecting voltage sensing inputs, close adherence to specified requirements regarding wire length is important to minimize signal degrading and the effects of electromagnetic noise interference induced along the connecting conductors. Current input signals, which are not as sensitive to noise as voltage signals, are typically not distance limited. Current sensing input modules typically accept analog data over the range of 4 mA to 20 mA, but can accommodate signal ranges of –20 mA to 120 mA. The loop power may be supplied by the sensor or may be provided by the analog output module as illustrated in Figure 2-24 . Shielded twisted pair cable is normally recommended for connecting any type analog input signal.

The *analog output interface module* receives from the processor digital data, which are converted into a proportional voltage or current to control an analog fi eld device.

The transition of a digital signal to analog values is accomplished by a digital-to-analog (D/A) converter, the main element of the analog output module. An analog output signal is a continuous and changing signal that is varied under the control of the PLC program. Common devices controlled by a PLC analog output module include instruments, control valves, chart recorder, electronic drives, and other types of control devices that respond to analog signals.

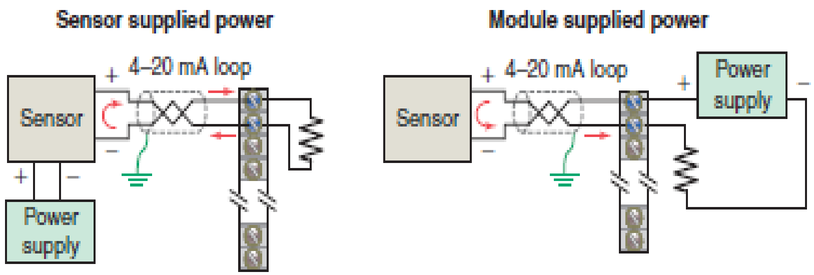

Figure 2-24 Sensor and analog module supplied power.

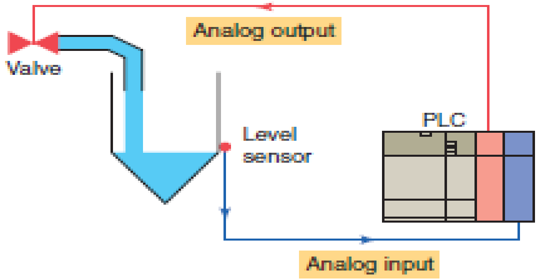

Figure 2-25 Typical analog I/O control system.

Figure 2-27 Thumbwheel switch.
Source: Photo courtesy Omron Industrial Automation, www.ia.omron.com.

Figure 2-25 illustrates the use of analog I/O modules in a typical PLC control system. In this application the PLC controls the amount of fluid placed in a holding tank by adjusting the percentage of the valve opening. The analog output from the PLC is used to control the flow by controlling the amount of the valve opening. The valve is initially open 100 percent. As the fluid level in the tank approaches the preset point, the processor modifies the output, which adjusts the valve to maintain a set point.

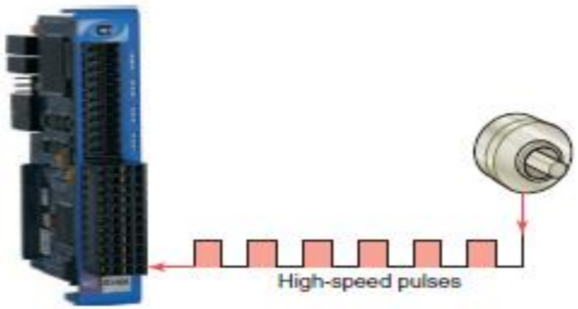

Figure 2-26 High-speed counter module.
Source: Courtesy Control Technology Corporation.

2.4 Special I/O Modules

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

HIGH-SPEED COUNTER MODULE

The high-speed counter module is used to provide an interface for applications requiring counter speeds that surpass the capability of the PLC ladder program. High-speed counter modules are used to count pulses (Figure 2-26) from sensors, encoders, and switches that operate at very high speeds. They have the electronics needed to count independently of the processor. A typical count rate available is 0 to 100 kHz, which means the module would be able to count 100,000 pulses per second.

THUMBWHEEL MODULE

The thumbwheel module allows the use of thumbwheel switches (Figure 2-27) for feeding information to the PLC to be used in the control program.

TTL MODULE

The TTL module (Figure 2-28) allows the transmitting and receiving of TTL (Transistor-Transistor-Logic) signals. This module allows devices that produce TTL-level signals to communicate with the PLC's processor.

Figure 2-28 TTL module.
Source: Courtesy Control Technology, Inc.

ENCODER-COUNTER MODULE

An encoder-counter module allows the user to read the signal from an encoder (Figure 2-29) on a real-time basis and stores this information so it can be read later by the processor.

BASIC OR ASCII MODULE

The BASIC or ASCII module (Figure 2-30) runs user written BASIC and C programs. These programs are independent of the PLC processor and provide an easy, fast interface between remote foreign devices and the PLC processor. Typical applications include interfaces to bar code readers, robots, printers, and displays.

Figure 2-29 Encoder.
Source: Photo courtesy of Allied Motion Technologies, Inc.

STEPPER-MOTOR MODULE

The stepper-motor module provides pulse trains to a stepper-motor translator, which enables control of a stepper motor (Figure 2-31). The commands for the module are determined by the control program in the PLC.

BCD-OUTPUT MODULE

The BCD-output module enables a PLC to operate devices that require BCD-coded signals such as seven- segment displays (Figure 2-32).

Figure 2-31 Stepper-motor.
Source: Courtesy Sherline Products.

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

PID MODULE

The proportional-integral-derivative (PID) module (Figure 2-33) is used in process control applications that incorporate PID algorithms. An algorithm is a complex program based on mathematical calculations. A PID module allows process control to take place outside the CPU. This arrangement prevents the CPU from being burdened with complex calculations. The basic function of this module is to provide the control action required to maintain a process variable such as temperature, flow, level, or speed within set limits of a specified set point.

MOTION AND POSITION CONTROL MODULE

Motion and position control modules are used in applications involving accurate high-speed machining and packaging operations. Intelligent position and motion control modules permit PLCs to control stepper and servo motors.

Figure 2-33 PID module.
Source: Courtesy Red Lion Controls.

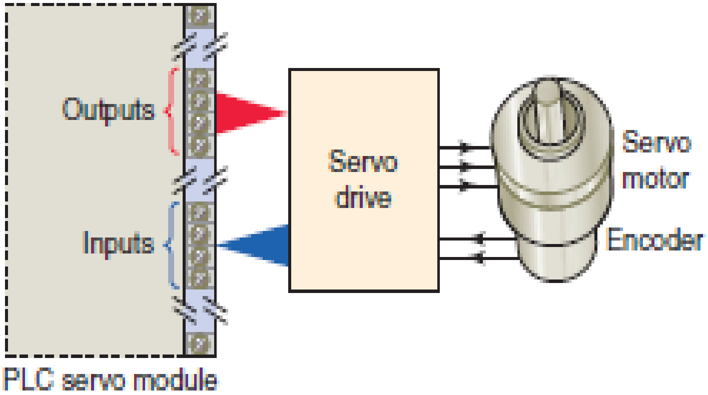

Figure 2-34 PLC servo module.

These systems require a drive, which contains the power electronics that translate the signals from the PLC module into signals required by the motor (Figure 2-34).

COMMUNICATION MODULES

Serial communications modules (Figure 2-35) are used to establish point-to-point connections with other intelligent devices for the exchange of data. Such connections are normally established with computers, operator stations, process control systems, and other PLCs. Communication modules allow the user to connect the PLC to high-speed local networks that may be different from the network communication provided with the PLC.

Figure 2-35 Serial communications module.
Source: Photo courtesy Automation Direct, **www.automationdirect.com**.

2.5 I/O Specifi cations

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

Typical Discrete I/O Module Specifications

NOMINAL INPUT VOLTAGE

This discrete input module voltage value specifies the magnitude (e.g., 5 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.

INPUT THRESHOLD VOLTAGES

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

NOMINAL CURRENT PER INPUT

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

AMBIENT TEMPERATURE RATING

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

INPUT ON/OFF DELAY

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

OUTPUT VOLTAGE

This AC or DC value specifies the magnitude (e.g., 5 V, 115 V, 230 V) and type (AC or DC) of user-supplied voltage at which a discrete output module is designed to operate. The output fi eld 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.

OUTPUT CURRENT

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

INRUSH CURRENT

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

SHORT CIRCUIT PROTECTION

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

LEAKAGE CURRENT

This value specifies the amount of current still conducting through an output circuit even after the output has been turned off. Leakage current is a characteristic exhibited by solid-state switching devices such as transistors and triacs and is normally less than 5 milliamperes. Leakage current is normally not large enough to falsely trigger an output device but must be taken into consideration when switching very low current sensitive devices.

ELECTRICAL ISOLATION

Recall that I/O module circuitry is electrically isolated to protect the low-level internal circuitry of the PLC from high voltages that can be encountered from fi eld 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.

POINTS PER MODULE

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

BACKPLANE CURRENT DRAW

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

Typical Analog I/O Module Specifications

CHANNELS PER MODULE

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

INPUT CURRENT/VOLTAGE RANGE(S)

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

OUTPUT CURRENT/VOLTAGE RANGE(S)

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

INPUT PROTECTION

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

RESOLUTION

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

COMMON-MODE REJECTION

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