CHAPTER

Output Modules

OBJECTIVES

After completing this chapter, you should be able to:

- describe the available types of output modules
- explain applications where analog output modules would be used
- define output module specifications from data sheets
- list the advantages and disadvantages of using relay versus solid-state output switching
- list the advantages and disadvantages of using solid-state versus relay output switching
- explain considerations when applying PLCs in hazardous locations

INTRODUCTION

The output section of a PLC system is the physical connection between the outside world and the central processing unit (CPU). Examples of discrete outputs include motor starter coils, pilot lights, solenoids, alarm bells, valves, fans, other control relays, or input start or stop signals to a variable-speed drive. All these devices have one thing in common: their signals are either ON or OFF, OPEN or CLOSED, YES or NO, or TRUE or FALSE.

Output modules generally fall into three classifications: discrete, analog, or specialty; they are also available in various switching voltages and configurations.

There are various ways to get information from the CPU's output status file to common hardware field devices. First, discrete output interface modules provide a method of getting discrete, or digital, signals out of the PLC to control discrete field devices. Second, ever-changing signals such as temperature control, or the 4–20 milliamp speed reference for variable-frequency drives, can be interfaced to the PLC using analog output modules.

This chapter will introduce discrete and analog output modules, their operating principles, types of modules available, advantages and disadvantages of using one type over the other, and basic interfacing principles.

DISCRETE OUTPUT MODULES

Much like discrete inputs, discrete outputs are the most commonly used type. Discrete output modules simply act as switches to control output field devices. They fall into two classifications: solid-state output switching and relay output switching.

Discrete output modules receive their operating power from the PLC's power supply, which comes from the backplane. Usually, the user must provide the power that the module output point switches to control the field devices. Figure 8-1 illustrates basic field wiring for a discrete 120 VAC output module.

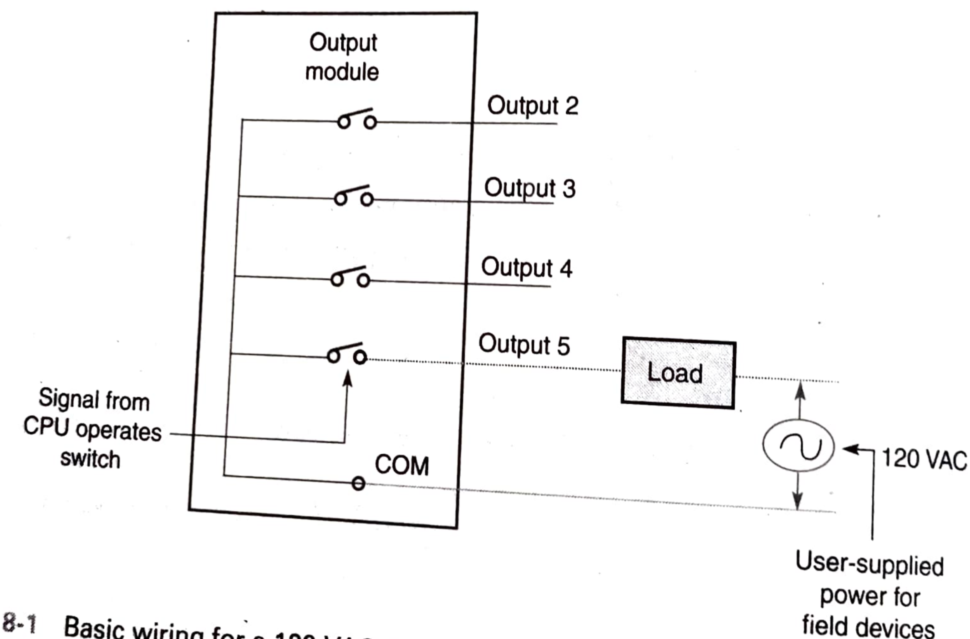

Figure 8-1 Basic wiring for a 120 VAC discrete output module.

Discrete output modules come in various signal levels and specifications. Listed in Figure 8-2 are common types and voltage levels of output modules that are available.

Operating Principles of Output Modules

Output modules are simply switching devices that carry out commands from the CPU. Each output point contains a switching device, which is located inside the output module and is turned on or off according to the bit value residing in that particular output status table address.

DISCRETE OUTPUT MODULES		
Solid-State Outputs		Relay Outputs
AC Output Modules	DC Output Modules	Relay Output Modules
12, 24, 48 VAC	TTL level	Relay Output
120 VAC	12, 24, 48 V dc	Isolated Relay Output
230 VAC	120 V dc	Relay Output
	230 V dc	
	24 V dc, Sink	
	24 V dc, Source	

Figure 8-2 Discrete output module output classifications.

During the portion of the processor operation where outputs are updated, the output status file values will be sent, one 16-bit word at a time, to the respective output modules. On accepting its output status word, the output module will turn each output on or off or will maintain the state of the field device as consistent with the associated bit in the output status file at that specific address. Figure 8-3 illustrates signal flow from the CPU through each step in the control of the field device.

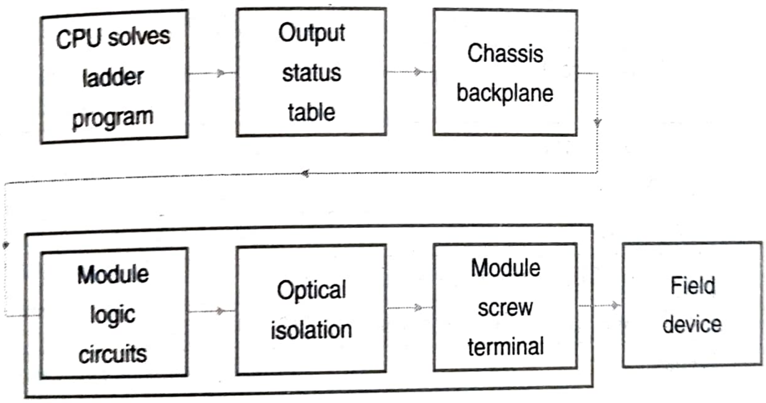

Figure 8-3 Signal flow from the CPU through an output module to the field device.

A typical AC output module contains circuitry as illustrated in Figure 8-4. A single AC output point consists of a latching circuit for the low-voltage (usually VDC or 12-18 V dc)

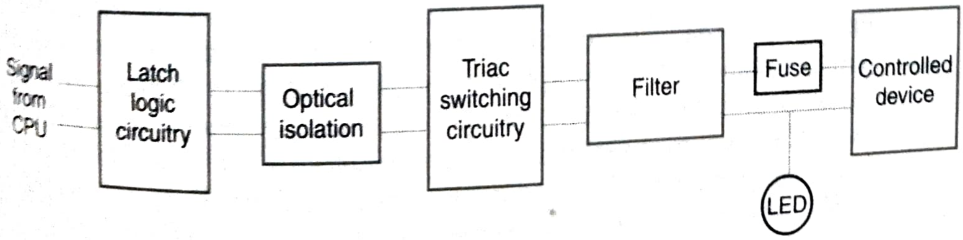

Figure 8-4 Block diagram of a typical output module.

logic signal sent by the CPU from the output status table. The ON or OFF signal represents the logical value of the output. If the output status table bit is a one, the ON signal will be latched into the logic circuitry block. This ON signal will be passed through the optical isolation circuitry to the block containing the switching hardware.

Solid-State Output Module Switching

In a solid-state AC output module, a triac is used to switch the AC high voltage and current controlling the ON or OFF state of the field hardware device. A triac is a solid-state device used to switch AC. The filter block will contain protective devices such as a metal oxide varistor (MOV). The MOV is used to limit peak voltage across the AC switching hardware to a safe level. The output point's LED alerts the operator that the output has been directed by the CPU to turn on. A fuse may also be included on the output line to protect the AC switching device from drawing too much current. If no fuse is provided in the module's circuitry, check your user's manual for instructions on the proper installation of a fuse in your field wiring. Although the PLC's power supply provides power to operate the output module, the power the triac switches to supply to the load must be provided by the user. Figure 8-5 lists specifications for an Omron CQM1-OA221 triac output module.

OMRON CQM1-OA221 TRIAC OUTPUT MODULE SPECIFICATIONS	
Switching Capacity, Maximum	0.4 amp at 100–240 VAC
Leakage Current	1 milliampere (mA) maximum at 100 VAC/ 2 mA maximum at 200 VAC
Residual Voltage	1.5 volts, 0.4 amp
ON Delay	6 milliseconds (ms) maximum
OFF Delay	$\frac{1}{2}$ cycle + 5 ms
Number of Outputs per Common	4
PLC Power Supply Consumption	110 mA at 5 V dc
Fuse	2 amps, one fuse per common. Fuse not user replaceable.

Figure 8-5 Data compiled from Omron CQM1 module specifications.

Switching DC Output Loads

DC output modules are used to control discrete loads by switching a power transistor rather than a triac. The functional operation of a DC output module is similar to the AC output module with the exception of the switching device. Being a solid-state device, the transistor-switching device is susceptible to surge currents and excessive voltages. Care should be taken to ensure that excessive voltages are not applied to the transistor, as they could cause excessive heat and a possible short circuit. Protecting the power transistor with a fast-acting fuse can reduce possible damage from excessive heat.

DC output modules, similar to DC input modules, are available in sinking and sourcing configurations. Figure 8-6 illustrates a sinking output module interfaced to a field device.

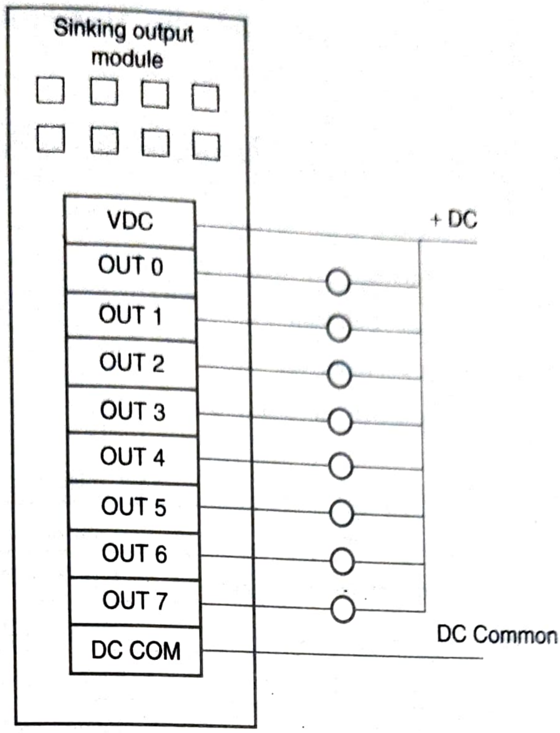

Figure 8-6 Sinking output module interface to field device.

Figure 8-7 illustrates a sourcing output module interfaced to a field device.

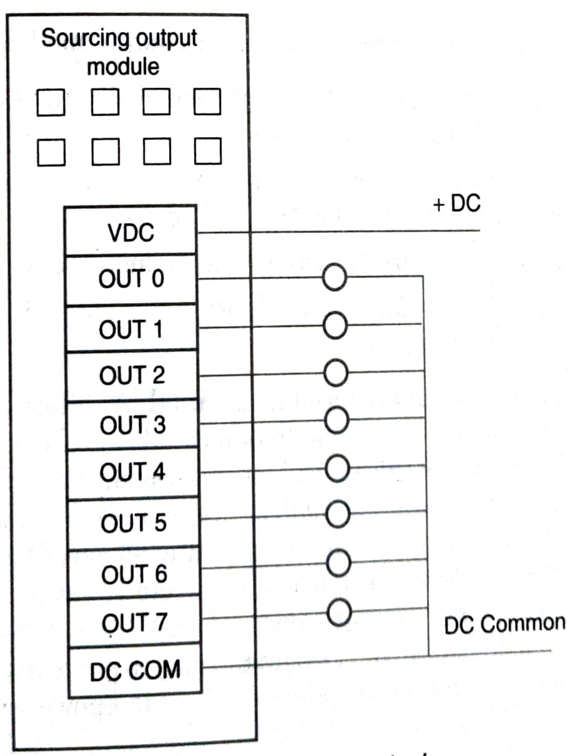

Figure 8-7 Sourcing output module interface to field devices.

Figure 8-8 lists the specifications for the Allen-Bradley SLC 500 sourcing output module number 1746-OB16.

SLC 500 SOURCING OUTPUT MODULE SPECIFICATIONS	
Operating Voltage	10–50 V dc
Number of Outputs	16
Output Points per Common	16
Backplane Current Draw	0.280 amp at 5 V dc
Maximum Signal Delay (Resistive Load)	ON = 0.1 millisecond OFF = 1.0 millisecond
Maximum OFF-State Leakage	1 milliamp
Minimum Load Current	1 milliamp
Continuous Current per Output Point	.5 amp at 30 degrees centigrade
Continuous Current per Module	8 amps at 30 degrees centigrade
Surge Current per Output Point	3 amps for 10 seconds
ON-State Voltage Drop	1.2 volts at 10 amps

Figure 8-8 Specifications compiled from Allen-Bradley discrete input and output modules product data.

The following terms are associated with output modules (see also Figure 8-8):

continuous current per module: the total of all output currents from all output points on a particular output module

continuous current per point: the maximum continuous output current each output point can supply to a load or field device

surge current: the inrush current to an inductive device

surge current per point: the total inrush current an inductive device can draw out of a single output point

The sinking or sourcing terminology used by different manufacturers for DC input modules also applies to DC output modules. Always check your manufacturer's wiring diagrams and module specifications before applying any module. DC output modules for the General Electric Series 90-30 PLC, for example, are identified as positive or negative logic rather than sinking or sourcing. A positive-logic output module acts as the source of current to the field device. The load is connected between the negative side of the power supply and the module's output screw terminal. A negative-logic output module sinks current from the field device, the load, to the negative side of the power supply. The field device is connected between the positive side of the power supply and the module's output screw terminal.

TRANSISTOR-TRANSISTOR LOGIC (TTL) OUTPUT MODULES

Transistor-transistor logic (TTL) output modules switch 5 V dc signals. A TTL output module allows for interface between the PLC and TTL-comparable devices. An example of a TTL interface would be interfacing a PLC to various 5 V dc field devices including integrated circuits and seven-segment LED displays.

Even though seven-segment displays are still used in some applications, they have been widely replaced with more modern human-machine interface devices that allow customized display screens to be developed with a personal computer and computer software.

RELAY OUTPUT MODULES

Relay output modules are also known as contact outputs or dry contact outputs. Even though relay output modules are used to switch AC or DC loads, usually relay outputs are used to switch small currents at low voltages, to multiplex analog signals, and to interface control signals to variable-speed drives.

Relay output modules use actual mechanical relays, one for each output point, to switch the output signal from the output status file. Figure 8-9 illustrates one point of a relay output module. Notice that the common goes to other relays in the group.

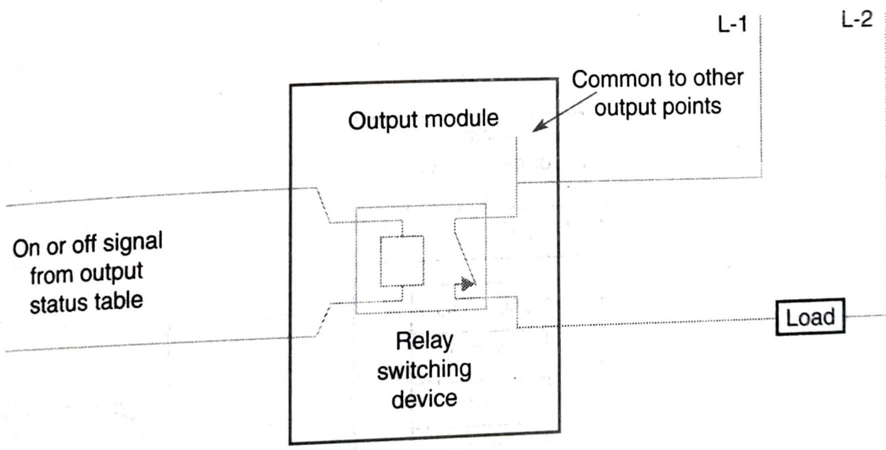

Figure 8-9 **Simplified single-point relay output.**

Relay output modules are available in three variations, depending on the manufacturer. Most manufacturers offer combination input and relay output modules. Combination relay modules usually come with two, four, or six 120 VAC inputs, and two-, four-, or six-relay outputs.

Figure 8-10 illustrates a 4-point 120 VAC input and a 4-point relay output combination module. Notice that relay outputs accept AC or DC signals.

Relay output modules are available with 8 or 16 outputs. Figure 8-11 illustrates an 8-point relay output module. Notice that the top four outputs have a single common,

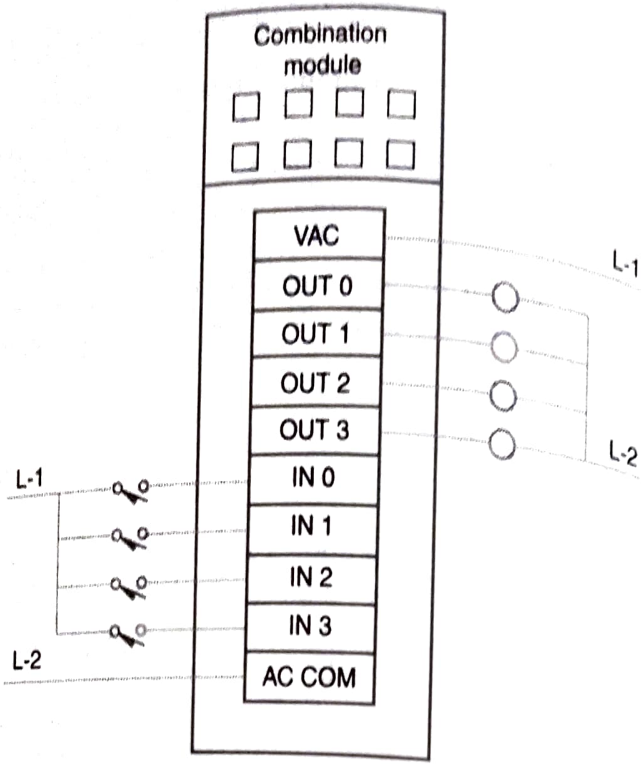

Figure 8-10 Combination 120 VAC input and relay output module.

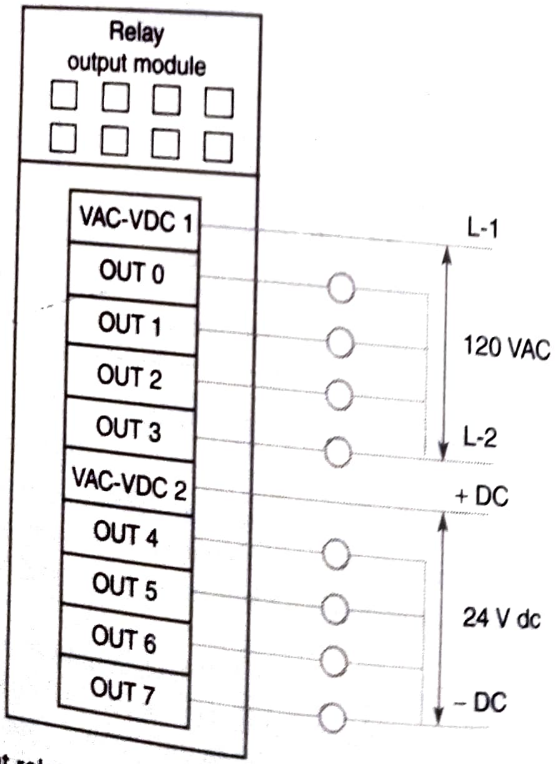

Figure 8-11 Eight-point relay output module.

whereas the bottom four outputs also have their own common. Separating the commons and their associated four outputs into two groups provides users with the flexibility to have one group switch one voltage type or level, say 120 VAC, while the other group of four outputs can switch a different voltage type or level, like 24 V dc.

Figure 8-12 lists module specifications for the General Electric Series 90-30 PLC normally open, relay output module IC693MDL940 (2 amp, 16 point).

GENERAL ELECTRIC RELAY OUTPUT MODULE SPECIFICATIONS FOR IC693MDL940	
Rated Voltage AC DC	 120/240 volts 24 volts
Operating Voltage AC DC	 5 to 30 volts 5 to 250 volts
Outputs per Module Output Grouping	16 4 per common
Isolation	1,500 volts between field side and logic side 500 volts between groups
Maximum Load, Pilot Duty Maximum Load per Common	2 amps maximum 4 amps maximum
Minimum Load	10 mA
Maximum Inrush	5 amps
ON Response Time	15 ms maximum
OFF Response Time	15 ms maximum
Power Consumed from Power Supply (All outputs on) 5 volts from Backplane 24 volts from Backplane	 7 mA 135 mA

Figure 8-12 Compiled from GE Fanuc Automation module specifications data, Series 90-30 Programmable Controller I/O Specifications Manual.

A common application for relay output modules is switching start, stop, and reverse control signals for a variable-speed drive. Figure 8-13 illustrates the wiring of a control wiring terminal block from an Allen-Bradley Bulletin 160 variable-speed drive to an SLC 500 1746-OWA relay output module. This is a similar relay output module to that illustrated in Figure 8-11. Since the drive provides 12 volts of power for the control circuit, the output module only has to provide a contact closure on output four, the reverse signal; output five, the start signal; and output seven, the stop signal.

This drive has eight preset speeds programmed by the operator into the drive's memory. The selection of different speeds is achieved by opening and closing preset switch

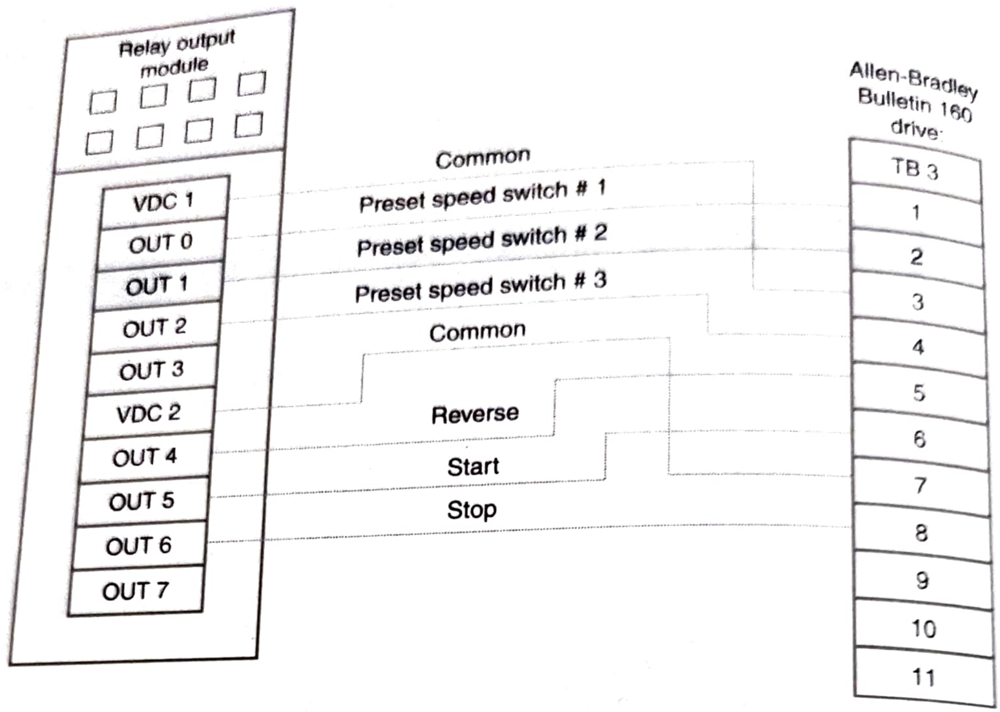

Figure 8-13 Variable-speed drive control interface to an SLC 500 1746-OWA relay output module.

one, output 0; preset switch two, output 1; and preset switch three, output 2, in the proper sequence. Remember from Chapter 4 that three bits can be arranged to reflect eight different binary combinations. These eight binary combinations, when switched by the PLC and input into the drive, select at which of the eight preset speeds the drive will run.

Relay output modules are also available with isolated outputs. In this design, an 8-point, isolated relay output module has a separate incoming line to supply power to the switching portion of each physical relay. Figure 8-14 illustrates an isolated relay output module. Notice the separate IN and OUT signal connections.

Isolated relay output modules have each output point isolated from all the other points. Isolated relay output modules are available with normally open and normally closed form C relays.

The advantage of an isolated relay output module is that since each relay is isolated from the others and has its own common line, each relay and its associated output point can control any voltage level that is compatible with its contacts.

One isolated relay output module could control field devices with 120 VAC, 120 V dc, 230 VAC, 24 V dc, 12 V dc, and 5 V dc, all from one module.

Because these modules use electromechanical relays as their switching devices, there are current limitations and different life expectancies in comparison to solid-state switching

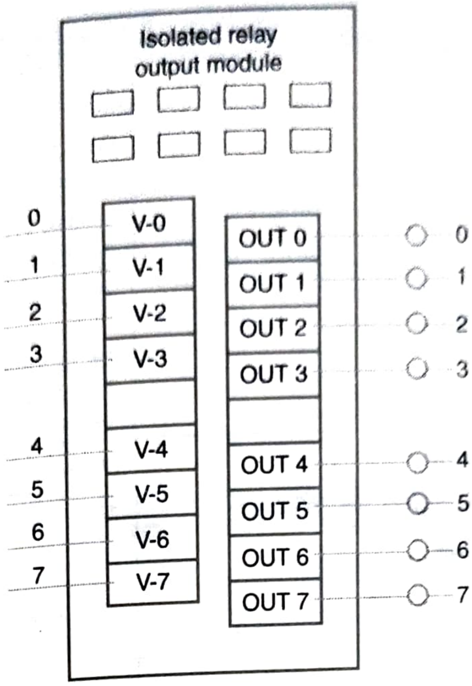

Figure 8-14 Eight-point isolated relay output module.

modules. Figure 8-15 lists contact life and current load specifications for the General Electric IC693MDL940 relay output module.

GENERAL ELECTRIC IC693MDL940 RELAY SPECIFICATIONS			
Voltage	Resistive Load in Amps	Lamp or Inductive Load in Amps	Contact Operations
24 to 120 VAC	2 1 .1	1 .5 .05	300,000 500,000 1,000,000
240 VAC	2 1 .1	1 .5 .05	150,000 200,000 500,000
24 V dc	NA 2 .1	1 .5 .05	300,000 500,000 1,000,000
125 V dc	.2	.1	300,000

Figure 8-15 Compiled from GE Fanuc Automation module specifications data.

Specifications for a Modicon Quantum Series PLC 16-point relay output module are listed in Figure 8-16.

MODICON QUANTUM PLC RELAY OUTPUT MODULE SPECIFICATIONS	
Number of Output Points	10 normally open
LEDs	One green LED for each output point to indicate the point's ON or OFF status
Working Voltage	20–250 VAC 5–30 V dc
Maximum Load Current per Point	2 A max. at 250 VAC or 30 V dc at 60 degrees C ambient resistive load 1 A tungsten lamp load 1 A at a power factor of 0.4 1/8 horsepower (hp) at 125/250 VAC
Maximum Frequency	60 hertz (Hz) resistive loads
Maximum Surge Current per Point	10 A capacitive load at 10 ms
Switching Capability	500 VA resistive load
Response Time	OFF to ON, 10 ms maximum ON to OFF, 20 ms maximum
Relay Contact Life, Mechanical	10,000,000 operations
Relay Contact Life, Electrical	200,000 operations, resistive at maximum voltage and current
Relay Type	Form A
Contact Protection	Internal varistor, 275 volts
Operating Current from Backplane	1,100 mA
Power Dissipation	5.5 watts plus .5 watt per point ON

Figure 8-16 Compiled from Modicon Quantum Automation Hardware Reference Guide.

MODULE SELECTION CONSIDERATIONS

There are several considerations when selecting an output module for your application. The primary issues are the number of operations, leakage current, and safe shutdown in case of a failure.

A solid-state output is used in applications where the output point will be turned on and off every few seconds for 24 hours a day every day will result in a probable life in the many times per hour or day. Solid-state switching devices theoretically have unlimited life. These devices are rated for hundreds of millions of operations, whereas a mechanical device will switch for only a few hundred thousand times. Switching a solid-state output on 20- to 30-year range. On the other hand, the same application with a mechanical output module would require replacement every few months.

By their very nature, solid-state devices leak current. As a result, leakage current may be adequate to turn on low-level actuators, or even turn on and keep on certain LED pilot lights or display devices. A relay output module may be required for these applications. The mechanical relay in a relay or contact output module is the only output circuit with no leakage current.

Even though today's PLCs are rugged and dependable devices, where safety is a primary concern, you should not depend on solid-state output modules. In many cases, solid-state switching devices will fail in a shorted, rather than an open, condition. By failing in a shorted (or ON) condition, such devices pose an added safety hazard. On the other hand, where safe shutdown is a necessity, an electromechanical relay can be jumpered or wired to fail in either an open or a closed state.

Figure 8-17 lists the specifications for a General Electric Series 90-30 solid-state output module.

GENERAL ELECTRIC SERIES 90-30, 120/240 VAC OUTPUT MODULE SPECIFICATIONS	
Number of Output Points	8, two groups of four
Output Voltage Range	85–264 VAC
Output Current	2 amps maximum per point 4 amps maximum per group (ambient dependent)
Inrush Current	20 amps maximum for one cycle
Maximum Load Current	100 mA
Output Leakage Current	3 mA maximum at 120 VAC 6 mA maximum at 240 VAC
Response Time	ON, 1 ms maximum OFF, ½ cycle maximum
Operating Current from Backplane	160 mA at 5 V dc, all outputs ON
Power Dissipation	5.5 watts plus .5 watt per point ON

Figure 8-17 Series 90-30 output module specifications.

CHOOSING THE PROPER OUTPUT MODULE

Take into consideration the advantages and disadvantages of each type of output module as you go through the selection process.

Advantages to Solid-State Switching

1. fast switching speeds
2. high reliability and almost infinite life
3. low power required to energize
4. no contact arcing
5. little or no switching noise

6. positive switching and no contact bounce
7. can be hermetically sealed—good for hostile environments

Disadvantages to Solid-State Switching

1. solid-state switch may be destroyed by an overload
2. solid-state devices tend to fail in the ON state
3. heat dissipation
4. expensive to purchase
5. possibility of false trips from electrical noise

Advantages to Relay Output Switching

1. contacts forgiving to a temporary overload
2. immune to false trips from electrical noise
3. little voltage drop across contacts
4. no restrictions when connecting in series or parallel configurations
5. definite ON or OFF state, with contacts physically open
6. no leakage
7. contacts generate little heat
8. inexpensive to purchase

Disadvantages to Relay Output Switching

1. mechanical switching is slow
2. mechanical life is limited by demands of the load and the contacts
3. require 50 milliamps or more to energize
4. subject to contact arcing or welding
5. subject to contact bounce
6. cannot be completely sealed

Solid-state output modules, like relay output modules, are available in isolated outputs, too.

SOLATED OUTPUT MODULES

Isolated output modules operate the same as other discrete output modules with the exception that the isolated module has its own separate common. Isolated output modules are available as either AC output modules or relay output modules. Isolated output modules are also similar to isolated input modules in that they allow for interfacing output devices powered by different sources, different phases, or different grounds. Such output modules allow a single module to interface many different output voltage levels. Isolated output modules have fewer output points, as there are only two points per output address, one for the signal in and one for the isolated, or separate, return. Figure 8-18 illustrates

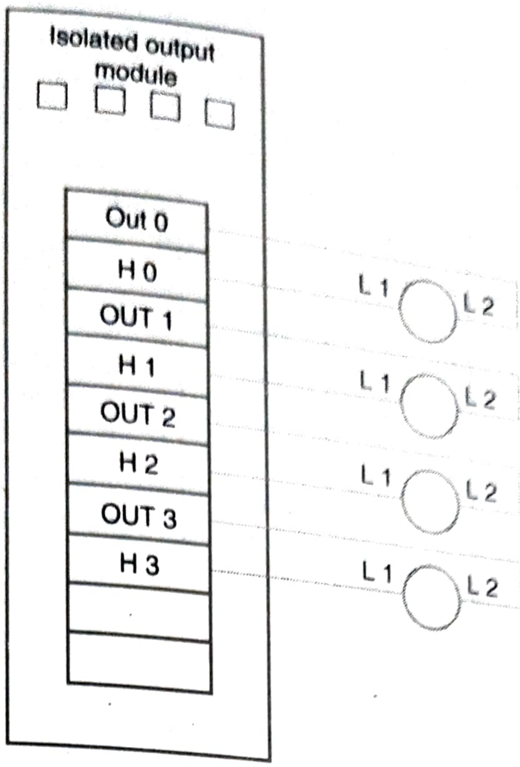

Figure 8-18 **AC isolated output module.**

an AC isolated output module. Notice that three different phases are being used to control three different output field devices.

Now that we have investigated the basic types of output modules and the advantages and disadvantages of both, let us see what you can do in cases where an output module is not capable of switching the load.

TERPOSING RELAYS

After looking at output module specifications, we see that most output modules switch between one-half and four amps. For the PLC to switch higher current loads, a mechanical relay needs to be placed between the high current load and the output module. The output module will switch the relay, and the relay will switch the load. This relay is called an "interposing relay." Figure 8-19 illustrates an output module switching an interposing relay coil, CR 1. Relay contacts CR 1-1, in turn, switch the motor starter coil.

RGE SUPPRESSION AND OUTPUT MODULES

Electrical noise and microprocessor equipment like PLCs do not work well together. Electrical noise is generated by many common industrial devices found in today's industrial environment. Electrical noise can cause microprocessor equipment to malfunction or lock up. It can be picked up on low-voltage communication cabling transmitting data

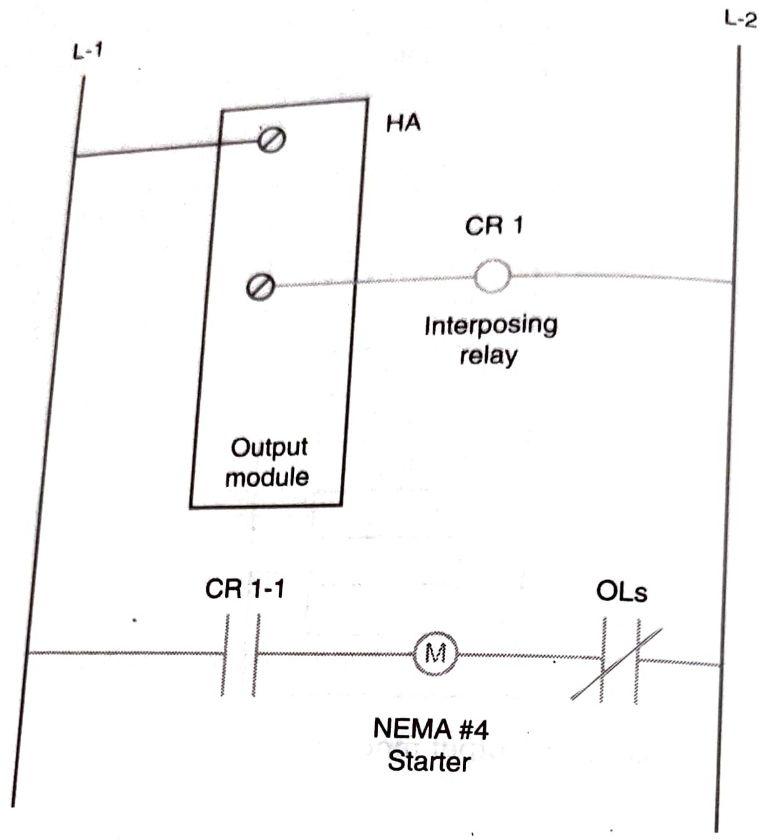

Figure 8-19 **Interposing relay switching a load that exceeds output module's switching capability.**

between PLCs or between a PLC and other hardware field devices. When noise is picked up on a communication cable, data can become corrupted. Corrupted data can bring a PLC network to a screeching halt.

Common devices such as motor starters, relays, contactors, solenoids, clutches and brakes, variable-frequency drives, and welding equipment are the primary culprits. Noise disturbances on the power line are generally caused by devices that have coils. These devices are called inductive devices. Noise is created when inductive devices are switched off.

Transmitted noise is created by devices that create radio frequency (RF) noise. Transmitted noise is generally caused from high-current applications such as welders and variable-frequency drives. Variable-frequency drives with newer Insulated Gate Bipolar Transistors (IGBT) switching transistors are known for generating large amounts of noise. In many cases, noise problems can be overcome by proper grounding, shielded cabling, inductors or chokes on communication lines, chokes on variable-frequency drive motor leads, and suppression devices on inductive devices such as motor starters or contractors.

Although most PLC output modules have built-in surge suppression to reduce the possibility of damage from high-voltage transients, it is a good idea to install additional surge suppression to any output module circuit switching an inductive load. Surge suppression should always be installed on a PLC output circuit where there is a set of hard contacts controlling an inductive field device. Install the surge suppressor, also called a snubber, across the coil of the field device. The surge suppressor will not only reduce the effects of voltage transients caused by interrupting the current to the inductive field device, it will also prevent electrical noise from entering the system wiring. Surge suppression will also help prolong the life of your output module's switching device.

Depending on the type of output module and its switching device, the suppression device may vary. As an example, the typical choice for a surge suppressor for a triac output module would be a metal oxide varistor (MOV). In some cases, a resistor-capacitor (RC) network is used for surge suppression. Surge suppressors must be carefully selected to suppress the switching transient of the particular inductive device. As an example, Allen-Bradley SLC 500 literature recommends a Harris MOV, part number V220MA2A, for 120 VAC inductive loads. MOVs are usually purchased from a local electronics supply house. Always consult your specific manufacturer's output module specification data sheet for selection of the correct suppressor. Note that most industrial control suppliers offer surge suppressors that are intended for installation on motor starters in conventional control circuits. In many cases these surge suppressors contain RC networks. RC network surge suppressors are typically not recommended for output modules with triac switching. DC output circuits, on the other hand, can usually use a diode for inductive load device suppression. In some cases, a diode such as a 1N4004, is just as acceptable as an MOV. Again, consult your module manufacturer's data sheets and always use the recommended surge suppressors.

HIGH-DENSITY I/O INTERFACE

High-density 32-point DC I/O modules are available for reducing panel space requirements by interfacing 32 input or output points to a single-slot module. Wiring 32 I/O points to the terminal block on the front of the module can become quite a challenge due to the high density of screw terminals and limited space. Figure 8-20 illustrates one example of wiring of high-density modules using a prewired cable that plugs into the front of the I/O module and connects to a remote DIN rail-mounted terminal block.

ANALOG OUTPUTS

Analog output modules accept a 16-bit output status word, which they convert to an analog value through a digital-to-analog converter. The converter (called a D-to-A converter) is part of the electronics inside the analog output module. Typical analog signals are 0 to 10 V dc, −10 to +10 V dc, 0 to 5 V dc, 1 to 5 V dc, 0 to 20 milliamps, −20 to +20 milliamps, or 4 to 20 milliamps. Analog output modules are selected to send out either a varying current or voltage signal.

An analog output could send a 4 to 20 milliamp signal to a variable-speed drive. The drive will control the speed of a motor in proportion to the analog signal received from the analog output module.

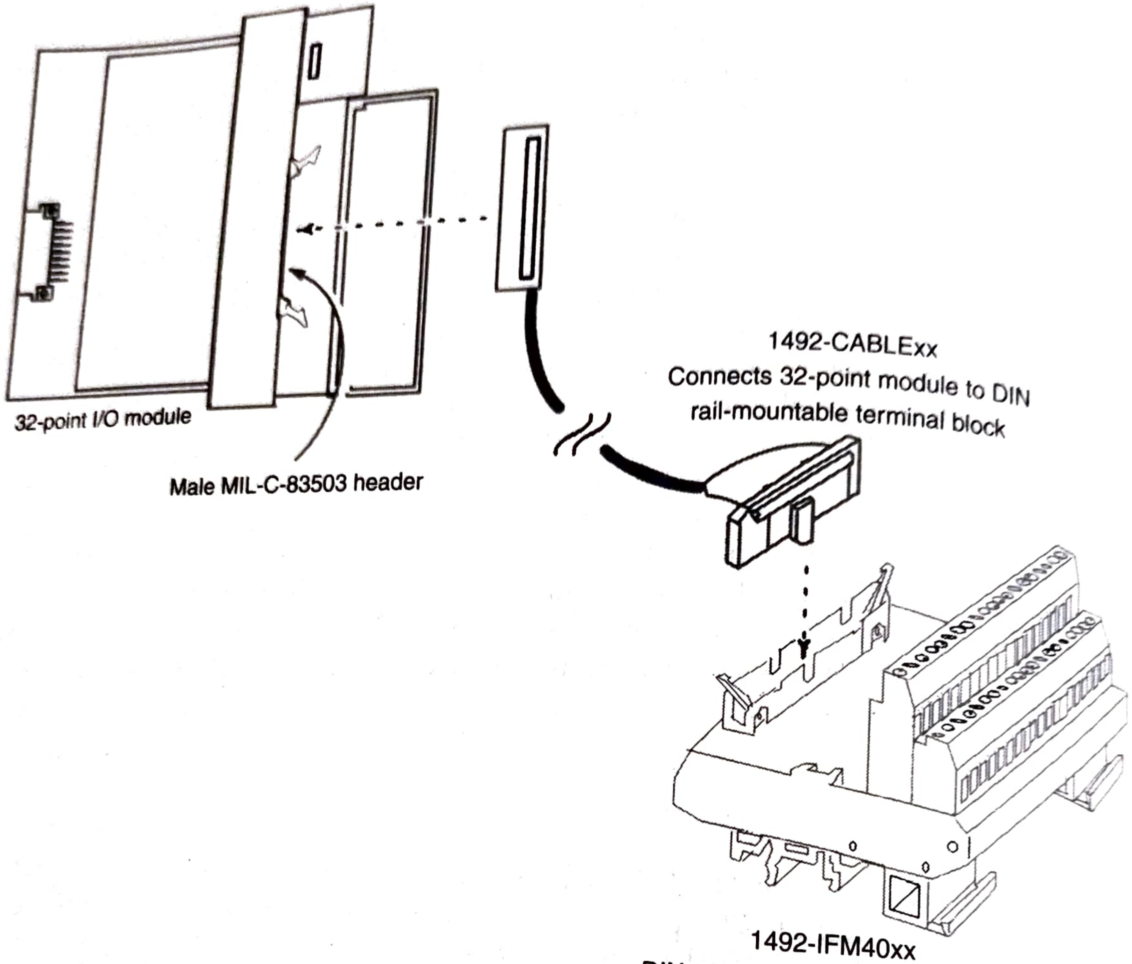

Figure 8-20 High-density I/O module wiring simplified by cabling I/O points to a nearby DIN rail-mounted terminal block. (Used with permission of Rockwell Automation, Inc.)

Another analog application could be controlling how far an analog water valve opens. A discrete valve is either fully open or fully closed. In many applications, more precise control is required than either a fully open or fully closed valve can provide. An analog valve can provide this precise control. An analog output module could output a 0 to 10 volt signal to an analog valve to provide the needed control. As an example, the output signal can be divided into 32,767 increments and represented in a 16-bit word. To achieve precision in controlling the valve, the 0 to 10 volt signal will be split into 32,767 steps, or possible output values, which correspond to 32,767 possible voltages between 0 and 10 volts. This will result in 32,767 possible valve positions. The voltage value output to the valve will control how far the valve will open or close. Figure 8-21 illustrates the valve position correlation to the module's output voltage. Column 3 represents the decimal value (between 0 and 32,767) of how far the program will direct the valve to open. Since the output

ANALOG SIGNAL COMPARISON FOR SAMPLE ANALOG VALUE OUTPUT		
Valve Position	Voltage Output Signal	Decimal Valve Output to Output Section
Full Open	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 8-21 Analog voltage correlation to one analog output module's data range.

module automatically converts the 16-bit output word to the proper analog voltage, the programmer only has to output the desired decimal integer value to the output status file. The value of the step will be directly correlated to the current signal output from the analog output module to the valve motor.

EMERGENCY-STOP SWITCHES AND PLC APPLICATIONS

Even though the typical emergency-stop (E-stop) palm button or switch may be thought of as a PLC input device, this is not the correct method of applying emergency-stop switches. There are important considerations regarding connecting E-stop switches in your control circuitry and the control of PLC-controlled field output devices in an emergency.

Emergency-stop switches should never be programmed in your PLC user program ladder diagram. Any emergency-stop switch needs to turn off all machine power. This is typically accomplished by a hardwired master control relay. Do not confuse this hardwired master control relay for E-stop control and the master control relay instruction programmed in a ladder program. The ladder program master control relay instruction should never be used in place of a hardwired master control relay. A hardwired master control relay provides a convenient means to shut down a system in an emergency. Typically, emergency-stop push and palm buttons, over travel limit switches, and system-stop switches are all normally closed devices wired in series with a hardware master control relay. The master control relay is wired to cut power to all input and output circuits. See Figure 8-22 for a typical master control wiring configuration. Remember always to

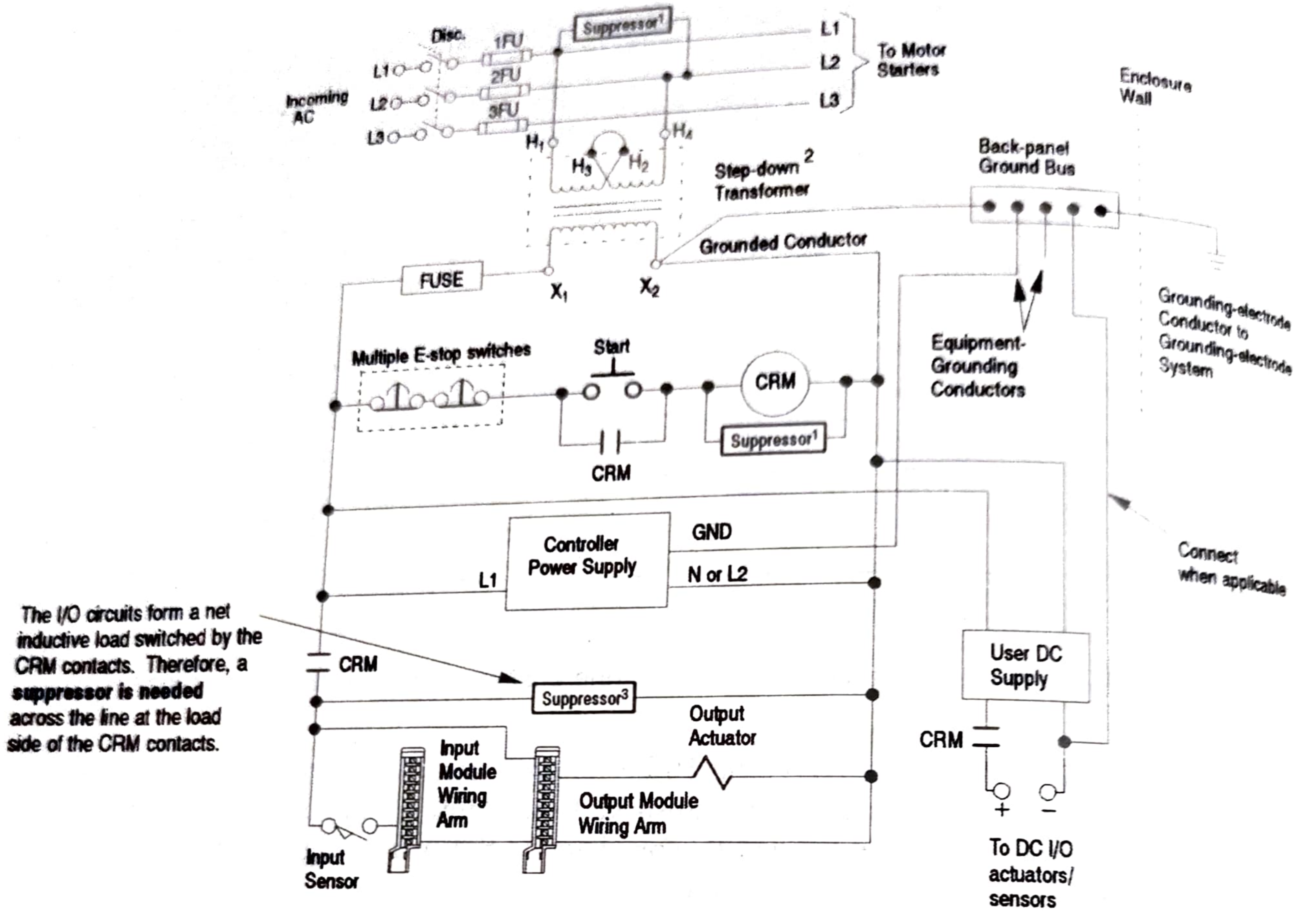

Figure 8-22 Typical master control relay wiring for emergency stop control. (Used with permission of Rockwell Automation, Inc.)

observe all local codes concerning the placement and labeling of E-stop switches and master relay control application for E-stop circuits.

When a master control relay is used to remove power from external PLC I/O circuits, power continues to be provided for the PLC controller itself (see Figure 8-22). Continuing power to the PLC's power supply enables the troubleshooter to use the PLC's diagnostic indicators. The troubleshooter can attach to the processor and monitor the PLC program and its status file's diagnostic information.

Important Rules Regarding Emergency-Stop Switches

1. Never program E-stop switches in the PLC program.
2. Always use a hardwired, hardware master control relay to cut power to all input and output circuits.

3. Do not control the master control relay instruction with the PLC.
4. The E-stop switch must turn off all machine power by turning off the master control relay.
5. Make sure E-stop switch contacts have sufficient current break ratings to handle breaking the circuit.
6. E-stop switches must be easy to reach.
7. *Always* check and follow all applicable codes concerning placement and labeling of E-stop switches and their associated master control relay.

I/O MODULES IN HAZARDOUS LOCATIONS

Many PLC manufacturers provide I/O modules that are rated for installation in hazardous locations. First, we need to define a hazardous area. A hazardous area or environment is one that contains amounts of explosive gases or dust. These hazardous materials may be present under normal operating conditions, or only in the event of equipment breakdown or an accident. The types of materials and the circumstances of their presence determine how the area is classified. Hazardous materials are divided into three classes, as defined by Underwriters Laboratories (UL) and the Canadian Standards Association (CSA). Class I includes flammable gases or liquid vapors that may ignite or explode. Class II is for combustible dust. Class III covers ignitable fibers or materials that produce combustible flyings (airborne debris from manufacturing processes such as cutting or grinding).

Classes are further broken down into divisions. The division identifies the conditions in which the hazard is present. Division 1 is an area where the hazard specified in the class can exist under normal operating conditions. Division 2 specifies that the hazardous materials as specified in the class are handled, processed, or used, but under normal operating conditions, these materials are either in closed containers or closed systems. Under Division 2, the hazardous materials are only present if they escape during equipment failure or accident.

Last, hazardous materials are classified by groups. Materials are grouped by their common range of ignition temperatures or explosion pressures.

A number of PLC manufacturers offer PLC hardware that is certified as Class I; Groups A, B, C, or D; Division 2. This certification means that the PLC can operate in an environment where volatile flammable liquids or gases are handled, processed, or used. Under normal conditions the hazard is either contained or removed by mechanical ventilation. Also included in Class I, Division 2, are manufacturing areas that are next to Class I, Division 1, areas and where hazardous gases or vapors might occasionally be present. (Refer to the National Electrical Code for the full text on hazardous classified locations.)

Potential Class I hazardous locations include petrochemical plants, petroleum refining or distribution facilities, dry-cleaning plants, dip tanks, solvent extraction plants, spray paint or finishing areas, aircraft hangars, and fueling areas.

HARDWARE CONSIDERATIONS BEFORE INSTALLING PLCs IN CLASS I, DIVISION 2, AREAS

1. Ensure that the PLC and its associated hardware are all certified as Class I, Division 2.
2. Verify that all electrical equipment installed in a Class I, Division 2, area falls within operating temperature codes.
3. All devices interfacing with the PLC must be Class I, Division 2, certified. This includes push buttons and pilot lights.
4. Follow National Electrical Code wiring methods.
5. Follow the manufacturer's installation instructions on all hardware devices.
6. Never install, remove, or operate any device that could cause an electrical arc while the circuit is alive.
7. Always check and follow local codes for the installation and operation of any equipment in a hazardous location.

Always carefully check your hardware against any hazardous rating standards before installation.

SUMMARY

Early programmable controllers were strictly limited to discrete inputs and outputs. 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 controllers can be applied to practically any control problem due to their complete range of discrete and analog interface control advancements and abilities.

There are output modules available along with combination input and output modules. I/O modules typically are available as 4-, 8-, 16-, 24-, or 32-point modules. Discrete output modules interface to AC, DC, and +5 DC TTL voltage signals to control field hardware devices. Output modules are available in two configurations: AC or DC solid-state output switching or mechanical-relay output switching.

In this chapter we explored discrete and analog output modules and how these modules interface signals to real-world devices from a CPU and the output status file. We also explored the basic techniques of interfacing analog output modules to the programmable controller.

REVIEW QUESTIONS

1. Our system of I/O provides 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
E. input modules and output modules

2. Discrete output interface modules accept signals from field devices that are:
   A. analog devices
   B. digital devices
   C. two-state devices
   D. discrete devices
   E. A and B
   F. B and C
   G. B, C, and D
3. Discrete output modules act as a ________ to control output field devices.
4. Output modules fall into two classifications, ________ output switching or ________ output switching.
5. Most PLCs have solid-state output modules that can switch outputs with:
   A. +5 V dc
   B. 10–30 V dc
   C. 120 VAC
   D. 120–240 VAC
   E. 200–240 VAC
   F. All of the above are correct.
6. Relay outputs accept a wide range of voltages, usually ________ VAC and ________ V dc.
7. Typical discrete output devices include:
   A. motor starters
   B. alarm bells
   C. inductive proximity switches
   D. pilot lights
   E. solenoids
   F. A, B, D, and E
   G. all of the above
8. Discrete output modules receive their operating power from the PLC's power supply by way of the ________.
9. Power that the module output switches to control field devices must be provided by:
   A. the CPU
   B. the chassis backplane
   C. the user
   D. the master control relay
   E. A and B
   F. all of the above
10. Name five analog outputs.

11. What are the five main sections of an AC output module?
12. What is the purpose of the hardwired master control relay in your control circuit?
    A. The master control relay is the master controller of the PLC.
    B. The master control relay is the master control of input and output circuit power only.
    C. The master control relay is the master control of input and output circuit power and power to the CPU's power supply.
    D. The master control relay controls power to all local and remote PLC chassis.
    E. A and D are correct.
    F. B and D are correct.
13. Examples of discrete outputs include:
    A. motor starter coils
    B. pilot lights
    C. solenoids
    D. start or stop signals to a variable-speed drive
    E. A, B, and C
    F. all of the above
14. All discrete outputs have one thing in common; their signals are either:
    A. ON or OFF
    B. OPEN or CLOSED
    C. YES or NO
    D. TRUE or FALSE.
    E. A, B, and C
    F. all of the above
15. Analog output control includes:
    A. pressure regulation
    B. temperature regulation
    C. analog valve positioning
    D. variable-frequency drive speed reference
    E. A, B, and C
    F. all of the above
16. The output section of a PLC system is the physical connection between the outside world and the ________.
17. Output modules generally fall into three classifications: ________, ________, or ________.
18. Electrical isolation is provided so that there is no physical electrical connection between the CPU and field devices. How is isolation usually accomplished?
19. Analog output signals can be interfaced to the PLC using modules specifically designed to accept these variable signals. These modules are called ________ output modules.
20. A ________ PLC's ability to interchange modules to meet the immediate interface need makes it popular and versatile.

21. Output modules are available in various switching ________ and configurations.
22. Each output module accepts its associated 16-bit output status word from the ________ during the output update portion of the CPU operating cycle.
23. The output module's internal electronics automatically converts the output status word into a separate ON or OFF signal for each output ________ terminal to control its associated field device.
24. Discrete output interface modules provide a method of getting two-state, ________, or ________ signals out of the PLC to control field devices.
25. Changing signals like temperature control or the 4 to 20 milliamp speed reference for a variable-frequency drive are called ________ signals.