Sensors and Programmable Controls

Assignment 15 should be considered unrelated to assignments 16, 17, and 18, since its primary focus is on detection sensors while the other three assignments address topics related to programmable logic controllers (PLC). However, it does have an indirect relationship, since detectors and sensors do provide input signals to PLCs.

Your textbook defines a *detection sensor* as a "specialized type of measurement device used in an automated system. . . whose function is to detect the absence, presence, or distance of an object from a reference point, and the object to be detected as the target." A mechanical lever limit switch detects the presence or absence of an object by physical contact, while a proximity switch detects presence, absence, or distance of an object by applying electronic circuitry without physical contact. Your text goes into great detail in the operation of various types of proximity switches, as well as other detection sensors that use electronics in their ability to detect.

Assignments 16–18 discuss topics associated with programmable logic controllers. In the first assignment, you'll be introduced to the basics of PLCs. You'll be shown how basic ladder logic diagrams are used to illustrate the circuitry that a PLC controls, and be given an introduction to PLC components. The second assignment will get you started in programming a programmable logic controller by describing a typical processor scan cycle, discussing logic conditions, and applying basic types of instruction in programming a PLC. Finally, the last assignment digs more deeply into programming, including jump instruction commands, understanding shift registers, developing function tables, and identifying input/output (I/O) modules.

When you complete this lesson, you'll be able to

- Describe how a proximity switch operates
- Describe how a photoelectric sensor operates
- Draw a one-rung ladder logic diagram based on a simple control circuit

- Name five major components of a PLC
- Identify a jump command in a ladder logic diagram

ASSIGNMENT 15

Read pages 381–424 in the textbook, *Industrial Control Electronics: Devices, Systems, & Applications.*

As technology advances the development of detection sensors using inductance, capacitance, and light, the applications of mechanically operated limit switches are becoming fewer and fewer. However, many are still "out there" and must be maintained. Simply put, these switches are designed to operate an internal switch whenever a mechanical arm on the switch contacts or is contacted by the *target object.*

Common applications of mechanical limit switches are machine shop tool tables that move from side to side, manufacturing processes such as large shearing machines, and any other equipment that must limit or indicate the travel or position of a moving target.

As industrial and manufacturing equipment is replaced, so is the technology. Limit switches are no exception, with their replacements relying on such technology as inductance and capacitance to indicate the presence of an object without making physical contact with the target. There are advantages, including less wear and tear, ease in installation, and less overall maintenance. However, with the new technology comes the necessity of learning about it, which is the primary reason for these reading assignments.

Although defective inductive and capacitive proximity switches are generally replaced and not repaired, it's good to know their internal makeup and how they operate in order to facilitate troubleshooting a malfunctioning application that contains one or more of these switches. Your book does a good job of describing the components and operations of various types of proximity switches. You'll also learn some of the techniques and methods that can be applied in positioning these switches with respect to the target so that the most effective and accurate detection is made possible.

Although inductive and capacitive proximity switches share many similarities, one major difference between them is that inductive devices are capable of detecting only conductive targets, whereas capacitive switches can detect the presence of both conductive and nonconductive targets. Detection of a target in a capacitive proximity switch is registered any time an object enters the electrostatic field produced by a capacitor within the switch.

There are more mechanically operated limit switches replaced with inductive proximity switches than capacitive switches because of cost and ease of installation. Conductive proximity switches are widely used in processes that involve liquids, powder, or granular materials.

Another type of detection device is the *Hall-effect sensor,* which detects the presence of a magnetic field. It gets its name from the fact that it incorporates a flat rectangular piece of P-type semiconductor (called a *Hall generator*) in its detector circuitry. When energized, a positively charged current flows through the material when a magnetic field isn't present, producing a zero voltage at the output terminals. However, when a magnetic field is detected, the charged carriers are deflected and cause a voltage output. There are various types of Hall-effect sensors, depending on the input requirements of associated circuitry.

Photoelectric sensors that detect light have been on the market for some time now, and have proven to be a very reliable method of detection. These types of devices generally require two components: a light source and a detector. However, both parts are often housed within the same enclosure, and use some type of reflector to reflect the light back to the detector.

Ultrasonic sensors use high-frequency sound waves (beyond the range of human hearing) to detect objects. They come in two kinds. Ultrasonic *proximity switches* detect the presence or absence of a target. Ultrasonic *analog sensors,* by contrast, produce an output voltage or current proportional to their distance from a target.

Your responsibilities as a technician usually include installing, setting, troubleshooting, and maintaining these various types of sensors. As detection sensor technology advances, so must your knowledge of these sensors.

Your reading assignment provides a solid representation of some of the newer technology that's now being applied in detection sensing, and it will be to your advantage to spend some time absorbing Assignment 15 so that you understand their latest detection applications.

After you've carefully read pages 381–424 in the textbook, *Industrial Control Electronics: Devices, Systems, & Applications,* complete *Self-Check 15.* Check your answers with those provided at the back of your textbook. When you're sure that you understand the material from Assignment 15, move on to Assignment 16.

Self-Check 15

Answer Problems 1–37 (odd numbers only) on pages 424–425 of the textbook, *Industrial Control Electronics: Devices, Systems, & Applications.*

Check your answers with those on page 592 of your textbook.

ASSIGNMENT 16

Read pages 427–461 in the textbook, *Industrial Control Electronics: Devices, Systems, & Applications.*

Programmable logic controllers, or *PLCs,* represent the introduction of computerized control into the process and motor control fields. PLCs may be in the form of a host computer system, or they may be central processing units mounted in field control devices. Regardless of their appearance or location, they all apply sets of predetermined and preloaded rules or programs called *algorithms* to maintain process variables at set point.

Not only are PLCs applied in instrumentation for process control, they're frequently used in the systematic control of motors. Chapter 18 of your textbook focuses more on the application of PLCs in motor control than in process control. It introduces you to *ladder logic,* which uses ladderlike graphical representations of lines and symbols to illustrate the circuit paths and sequential operation of devices such as motor starter and relay coils and pilot lights. Included in these diagrams are switch contacts that sequentially cause a device to become energized or de-energized.

Technicians must be able to thoroughly interpret a ladder diagram if they intend to troubleshoot a multidevice control system. There's no way around this fact. You won't master ladder diagram interpretation after completing this reading assignment because of the limited device illustrations. But you'll have attained a basic knowledge that will help get you started in the right direction.

One of the best learning tools that you can apply after completing your reading assignment is to locate a set of ladder diagrams and practice interpreting them. Most apprentice technicians find ladder diagrams mind-boggling just from their appearance. Take time to reread your assignment and have a set of ladder logic diagrams readily available for your reference. Don't allow yourself to become frustrated in your first attempt at interpreting the drawings, but always start at the top rung. Once you've mastered interpreting the first rung, go to the second rung, and continue on until you've mastered the complete diagram. As a suggestion, it's best to start with a diagram that has a minimal number of rungs on the ladder so that you don't become overwhelmed at the very beginning. However, in the long run, the number of rungs doesn't necessarily determine the complexity of the diagram. If you can interpret one rung, you should be able to interpret a series of rungs.

Chapter 18 also gets you started in identifying the major components of a programmable logic controller, including the *rack assembly, power supply, input/output modules,* and *processing units.* Processing units include the *central processing unit (CPU), arithmetic logic unit (ALU),* and *memory storage.*

Most of us are aware that the CPU is the brain of the PLC, and provides the intelligence to interpret and execute computer-based programs that are permanently stored in the processor's memory. These programs are written to enable the PLC to perform ladder logic. The CPU also coordinates the operation of the ALC and the memory.

The last portion of this chapter touches lightly on *addressing.* The symbol of each element or ladder instruction must be assigned an address. There isn't enough information in your book to really give you an understanding of PLC addressing, but the examples listed *will* help you to identify an address as such when you see one. If your responsibilities will include programming a PLC, it will be in your best interest to advance your studies in PLC programming, including PLC addressing.

After you've carefully read pages 427–461 in the textbook, *Industrial Control Electronics: Devices, Systems, & Applications,* complete *Self-Check 16.* Check your answers with those provided at the back of your textbook. When you're sure that you understand the material from Assignment 16, move on to Assignment 17.

Self-Check 16

Answer Problems 1–35 (odd numbers only) on pages 462–463 of the textbook, *Industrial Control Electronics: Devices, Systems, & Applications.*

Check your answers with those on page 592 of your textbook.

ASSIGNMENT 17

Read pages 465–488 in the textbook, *Industrial Control Electronics: Devices, Systems, & Applications.*

If part of your responsibilities includes PLC programming, Assignment 17 will be of great help to you, as it covers the fundamentals of PLC programming.

The success of a programmable controller in achieving machine control is only as weak or as strong as the program written into its memory, and the power of its CPU. This is true because the execution of the program is performed by the CPU through a three-step process called a *process scan cycle.* This chapter describes the process scan and also examines the different types of ladder logic instructions required to write a program.

As a technician responsible for the operation and maintenance of PLCs, it's important that you know exactly what actions take place when the PLC is powered up. These actions can be divided into three primary sections: (1) update the input image table; (2) scan program instructions; and (3) update the output terminals. This three-step scanning process is continuous and is repeated many times each second. The time it actually takes to complete one cycle depends on the size of the program and the clock speed of the CPU. When CPUs *lock up,* it usually means that a scanning cycle has been interrupted by corrupt data in one of the three sections.

Writing ladder logic requires knowledge of *ladder logic language,* which uses symbols that are inserted into ladder rungs on a diagram. These symbols represent an instruction set that performs different types of On-Off operations. Generally speaking, the input conditions are represented by *contact symbols,* and the output instructions are represented by *coil symbols.* Knowing how to arrange multiple input signals so that multiple output devices operate in their proper sequence defines the basics of ladder diagram programming.

Ladder logic instructions and symbols differ slightly from relay ladder diagrams, which many technicians are already familiar with, but follow the same concept of sequential order. Having a previous knowledge of relay ladder diagrams (like those used to represent motor control circuits) will provide an edge in developing ladder logic instructions for PLCs. In motor control ladder diagrams, input devices such as push button, float, temperature, level, and other switches are usually represented by individual symbols that identify the specific type of device. However, in ladder logic instructions, input devices are shown as two vertical, parallel lines, regardless of the type of device. Similarly, output devices in relay ladder diagrams are typically shown as a circle with some identifying lettering enclosed in the circle, while ladder logic instructions use a symbol that resembles a set of open and closed parentheses.

Your textbook uses several typical application examples to help you along in interpreting and writing ladder logic instructions. However, you must always refer to the PLC manufacturer's documentation before attempting to write and install a program into the PLC. Language preferences and how programs are entered may differ from one PLC to another, but all should follow some standard form for writing ladder logic instructions.

Lastly, most PLCs have the ability to perform arithmetic operations, such as addition, subtraction, multiplication, and division. To perform these functions, data from two sources must be applied. One source may be a preloaded constant number in the program, while the other may be from an address location; however, both may not be constants from the program. There must be an outside source for the other data.

After you've carefully read pages 465–488 in the textbook, *Industrial Control Electronics: Devices, Systems, & Applications,* complete *Self-Check 17.* Check your answers with those provided at the back of your textbook. When you're sure that you understand the material from Assignment 17, move on to Assignment 18.

Self-Check 17

Answer Problems 1–35 (odd numbers only) on pages 488–489 of the textbook, *Industrial Control Electronics: Devices, Systems, & Applications.*

Check your answers with those on page 592 of your textbook.

ASSIGNMENT 18

Read pages 491–521 in the textbook, *Industrial Control Electronics: Devices, Systems, & Applications.*

This chapter may be a bit more difficult to follow than the previous chapter on PLC programming because it addresses some of the more advanced issues related to it, such as jump instruction commands, shift registers, sourcing and sinking I/O modules, analog input and output modules, and special-purpose I/O modules. However, taking your time in reading it, and even backtracking over information already read, can help you gain advanced knowledge in the subject of PLC programming.

Jump commands are nothing more than instructions that allow the normal sequential program execution to be skipped over if certain conditions exist. One advantage of using jump commands is that it allows the PLC to hold more than one program and scan only the portion of the program needed to perform the desired action. This reduces scan time and allows more scans to take place within a given period of time.

A jump command is represented by a ladder logic output symbol and is always preceded by at least one conditional input symbol on the same rung. All input conditions preceding the jump command output on that rung must be True in order for the jump command to be executed. A maximum of 256 jump commands are allowed per program, and it's possible to jump ahead or go back in the program when the jump command is executed.

An application where a jump command may be used is a multistep operation where some of the steps aren't always needed, based on certain conditions. An example of this might be where several types of parts are moving on a conveyor belt, with each requiring a different set of instructions for assembly. An optical sensor may be installed that reads the part to determine its type as it passes before the sensor. Depending on the part, a different rung will go to a True state as the part is read by the sensor. Once the complete rung is True, the jump command will cause the program to skip to the subroutine that contains the assembly operation instructions for that particular part.

PLC programming technicians are applying an extra tool from their toolbox whenever they use jump commands, and having the ability to understand how jump commands affect the overall execution of the program is absolutely necessary before applying them.

Another tool in the toolbox of PLC programming for the technician is a shift register. A *shift register* is used primarily to control a process on a conveyor system. Shift registers allow data to be entered from the right side of the register as either a logic value 1 or logic value 0. A clock pulse applied to the register will cause the data to shift one place to the left. In a conveyor system, the data is entered into the shift register as an object on the conveyor belt is inspected. Depending on the outcome of the inspection, the logic state may be either a 1 or a 0. Your text demonstrates this application by applying shift registers to a conveyor line in a brewery. Following each step given in your book will help you to understand the purpose and function of shift registers in industrial control, and how they may be applied in other processes.

Field devices that provide different switching signals based on whether they're in the On or Off condition are referred to as *discrete devices,* and connect to either the discrete input or the discrete output modules of the PLC. If you must select an input module for a PLC system, your textbook walks you through the process, step by step, and illustrates how relay contact switches provide discrete input signals. Chapter 19 also lists some common troubleshooting techniques that may be applied to troubleshooting I/O interfaces.

After you've carefully read pages 491–521 in the textbook, *Industrial Control Electronics: Devices, Systems, & Applications,* complete *Self-Check 18.* Check your answers with those provided at the back of your textbook. When you're sure that you understand the material from Assignment 18, complete the Lesson 5 Examination.

Self-Check 18

Answer Problems 1–31 (odd numbers only) on pages 521–522 of the textbook, *Industrial Control Electronics: Devices, Systems, & Applications.*

Check your answers with those on page 592 of your textbook.