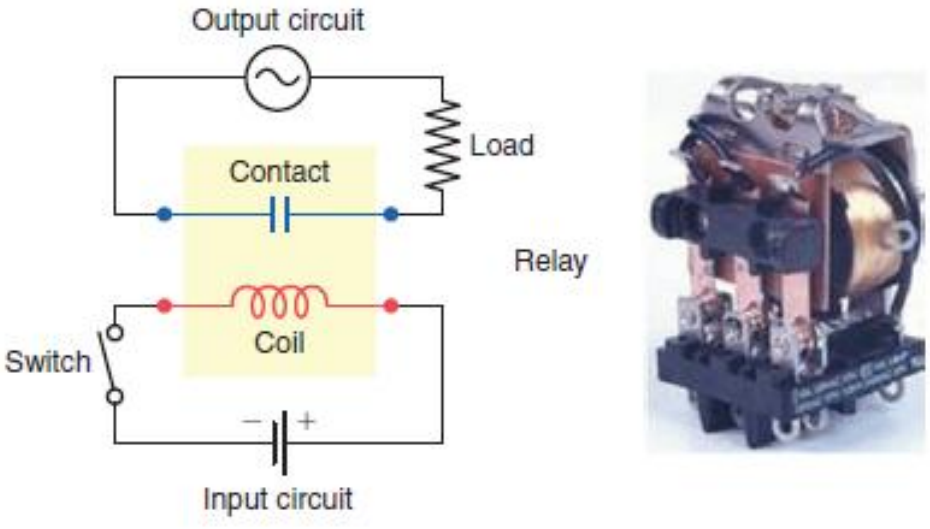
➢Chapter 6
Developing Fundamental PLC Wiring Diagrams and Ladder Logic Programs

❑Electromagnetic Control Relays

➢Although the PLC has replaced much of the relay control logic, electromagnetic relays are still used as auxiliary devices to switch I/O Field devices.

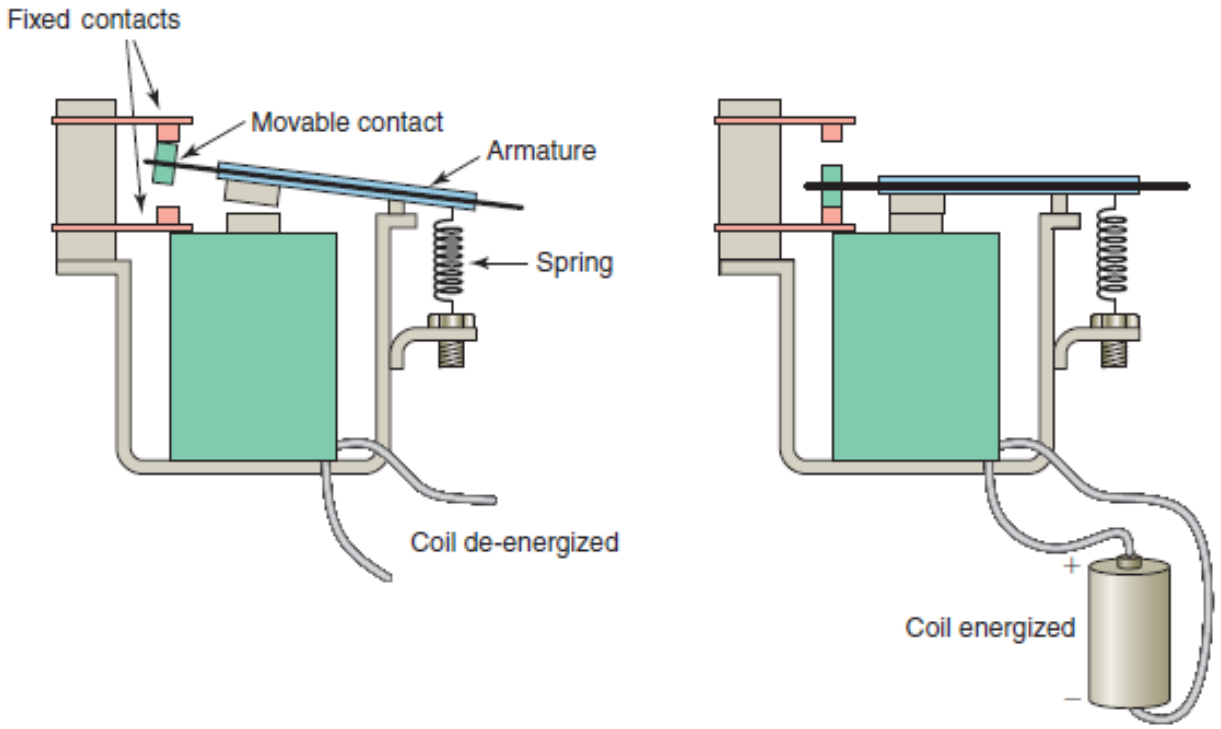
➢The programmable controller is designed to replace the physically small control relays that make logic decisions but are not designed to handle heavy current or high voltage



❑Electromagnetic Control Relays

➢An electrical relay is a magnetic switch. It uses electromagnetism to switch contacts.

➢A relay will usually have only one coil but may have any number of different contacts. Figure illustrates the operation of a typical control relay



❑Electromagnetic Control Relays

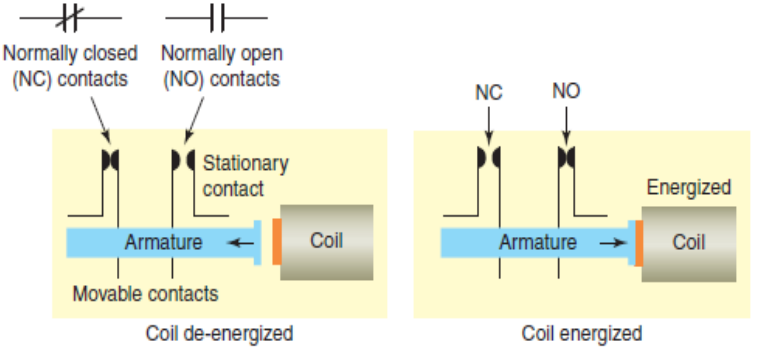
✓The symbol used to represent a control relay is shown in Figure.

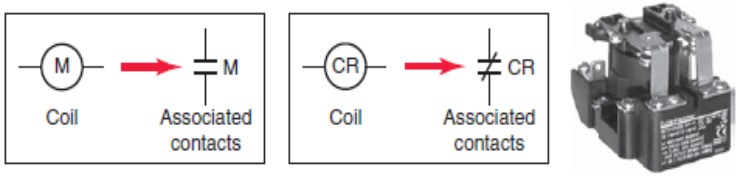
✓The letter M frequently indicates a motor starter, while CR is used for control relays.

✓*Normally open (NO) contacts are defined as those contacts* that are open when no current flows through the coil but that *close as soon as the coil conducts a current or is energized.*

✓*Normally closed (NC) contacts are closed when the* coil is de-energized and open when the coil is energized.

✓The contacts are usually rated between 5 and 10 amperes,with the most common rating for the coil voltage being 120 VAC.

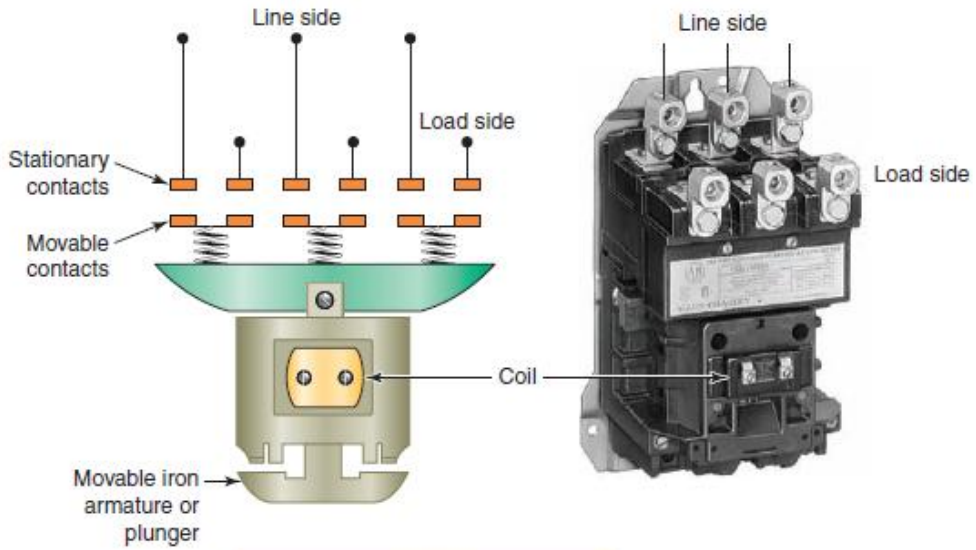




❑Contactors

✓A contactor is a special type of relay designed to handle heavy power loads that are beyond the capability of control relays.

✓Figure shows a three-pole magnetic contactor.



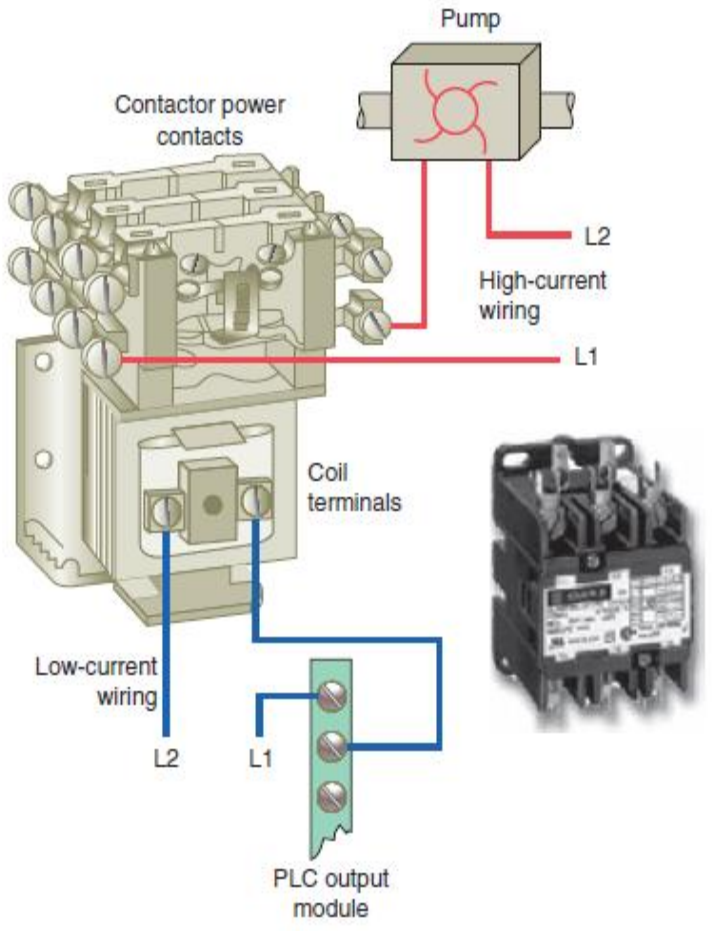
❑Contactors

✓Programmable controllers normally have an output capacity capable of operating a contactor coil, but not that needed to operate heavy power loads directly.

✓Figure illustrates the application of a PLC used in conjunction with a contactor to switch power on and off to a pump.

✓The output module is connected in series with the coil to form a low-current switching circuit.

✓The contacts of the contactor are connecte in series with the pump motor to form a high-current switching circuit.



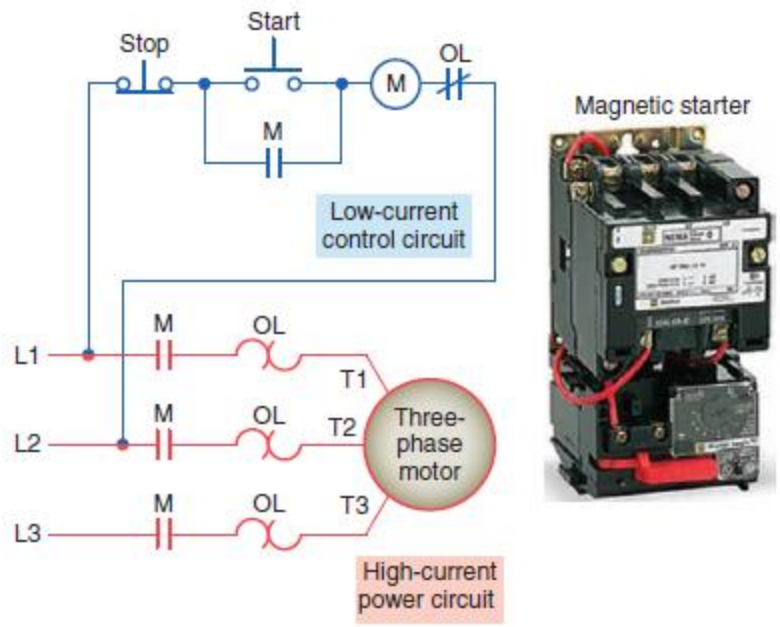
❑Motor Starters

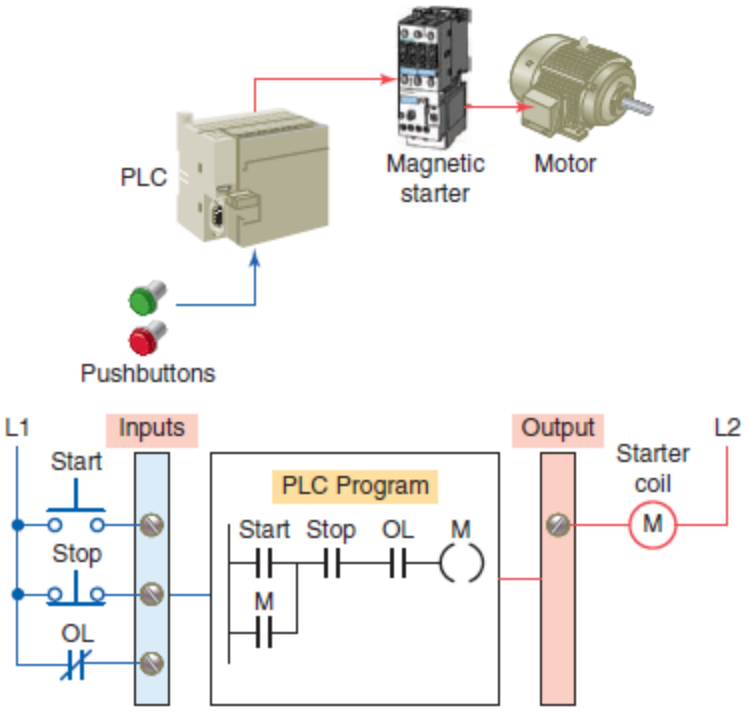
✓A *motor starter is designed to provide power to motors.*

✓The motor starter is made up of a contactor with an *overload relay attached physically and electrically to it as illustrated* in Figure .

❑Motor Starters

➢Figure shows the diagram for a typical three-phase, magnetic motor starter.





❑Manually Operated Switches

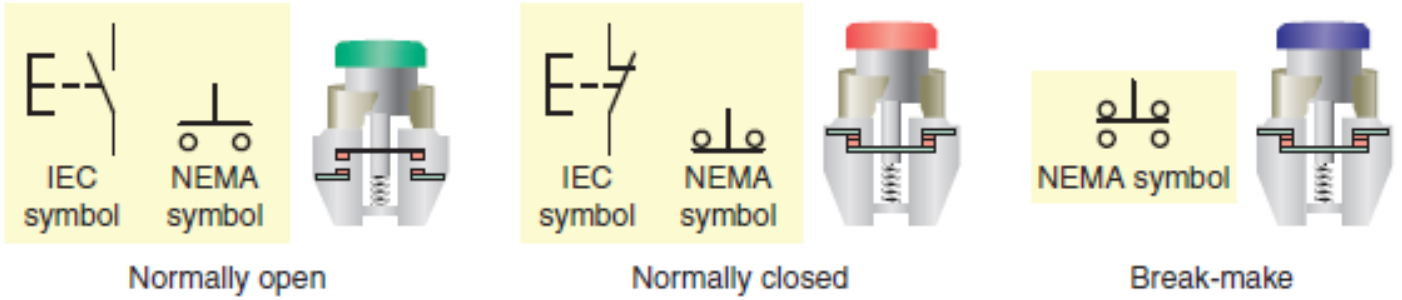
➢*Manually operated switches are controlled by hand.*

➢These include toggle switches, pushbutton switches, knife switches, and selector switches.

➢ *Pushbutton switches are the most common form of* manual control.

➢ A pushbutton operates by opening or closing contacts when pressed.

Figure shows commonly used types of pushbutton switches, which include:

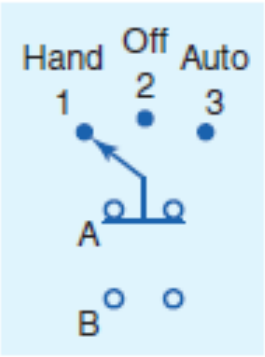


❑Manually Operated Switches

- The *selector switch is another common manually operated* switch.
- The main difference between a pushbutton and selector switch is the operator mechanism.
- A selector switch operator is rotated (instead of pushed) to open and close contacts of the attached contact block.

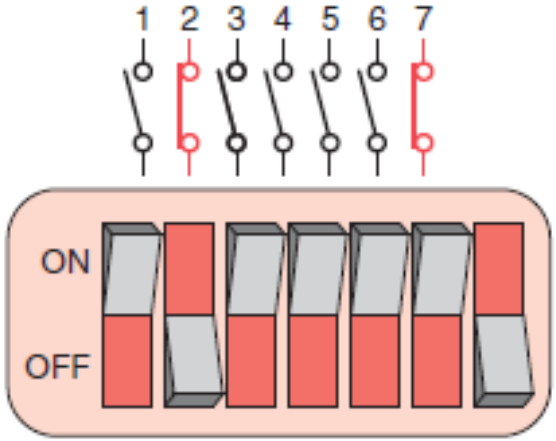
Position	Contacts	
	A	B
1	X	
2		
3		X

Symbol



❑Manually Operated Switches

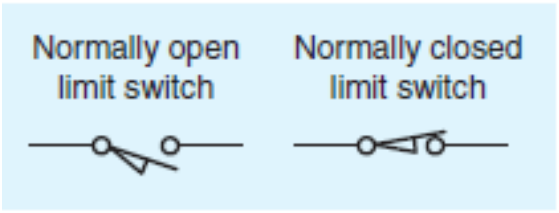
➢Dual in-line package (DIP) switches are small switch assemblies designed for mounting on printed circuit board modules

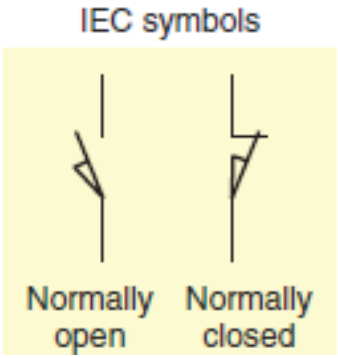


❑Mechanically Operated Switches

➢A *mechanically operated switch is controlled automatically* by factors such as pressure, position, or temperature.

➢Limit switches are designed to operate only when a predetermined limit is reached, and they are usually actuated by contact





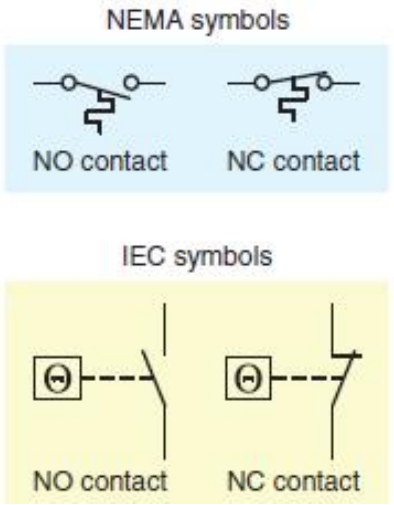
❑Mechanically Operated Switches

➢ the *temperature switch, or thermostat, shown in Figure* is used to sense temperature changes.

➢Although there are many types available, they are all actuated by some specific environmental temperature change.

Temperature switches open or close when a designated temperature is reached

Programmable thermostat



❑Mechanically Operated Switches

➢ Pressure switches, such as that shown in Figure, are used to control the pressure of liquids and gases.

➢Although many different types are available, they are all basically designed to actuate (open or close) their contacts when a specified pressure is reached.

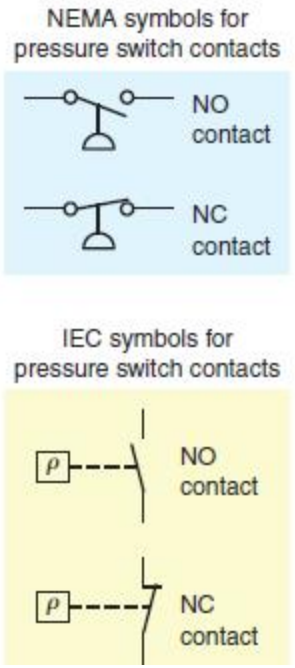
➢Pressure switches can be pneumatically (air) or hydraulically (liquid) operated switches.

❑Mechanically Operated Switches

➢ *Level switches are used to sense liquid levels in vessels* and provide automatic control for motors that transfer liquids from pumps or into tanks.

➢They are also used to open or close piping solenoid valves to control fluids.

➢The float switch shown in Figure

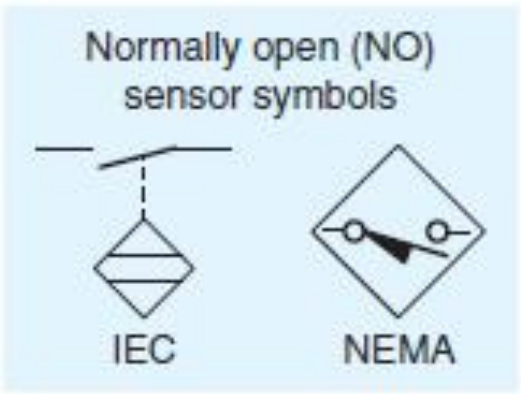


❑Sensors

➢ Proximity Sensor

✓Proximity sensors or switches, such as that shown in Figure are pilot devices that detect the presence of an object (usually called the target) *without physical contact.*

✓These solid-state electronic devices are completely encapsulated to protect against excessive vibration, liquids, chemicals, and corrosive agents found in the industrial environment.



❑Sensors

➢ Proximity Sensor

✓Proximity sensors are used when:

• The object being detected is too small, lightweight, or soft to operate a mechanical switch.

• Rapid response and high switching rates are required, as in counting or ejection control applications.

• An object has to be sensed through nonmetallic barriers such as glass, plastic, and paper cartons.

• Hostile environments demand improved sealing properties, preventing proper operation of mechanical switches.

• Long life and reliable service are required.

• A fast electronic control system requires a bouncefree input signal.

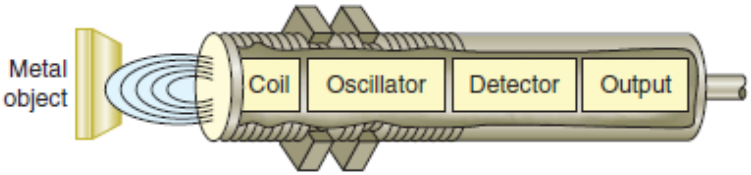
❑Sensors

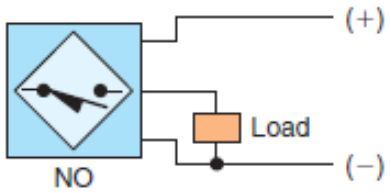
➢ Proximity Sensor

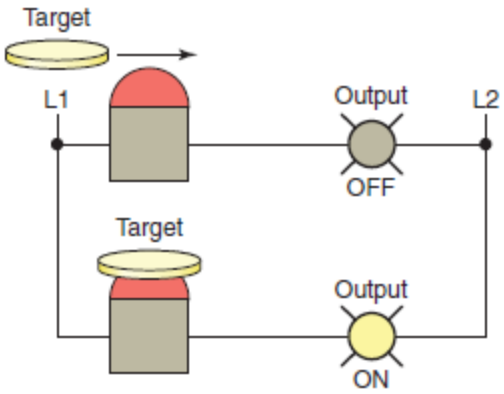
✓Proximity sensors operate on different principles, depending on the type of matter being detected.

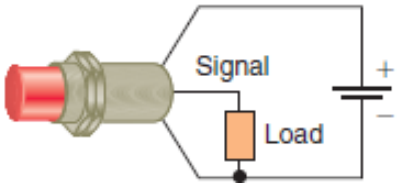
✓The block diagram for an inductive proximity sensor is shown in Figure and

✓Most sensor applications operate either at 24V DC or at 120V AC







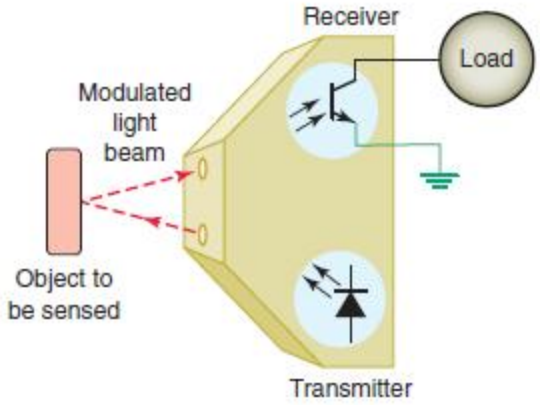


❑Sensors

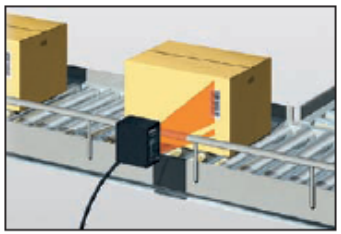
Light Sensors

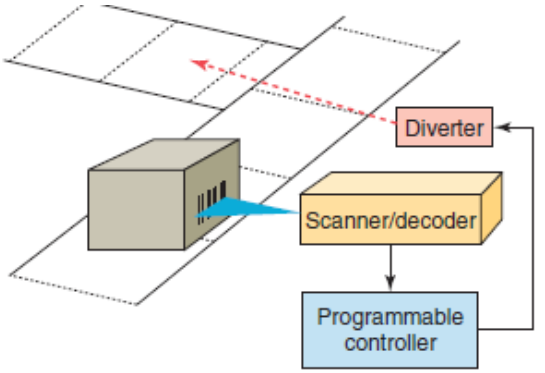
➢A *photoelectric sensor is an optical control device* that operates by detecting a visible or invisible beam of light and responding to a change in the received light intensity.

➢Photoelectric sensors are composed of two basic components: a transmitter (light source) and a receiver (sensor), as shown in Figure .



Bar code



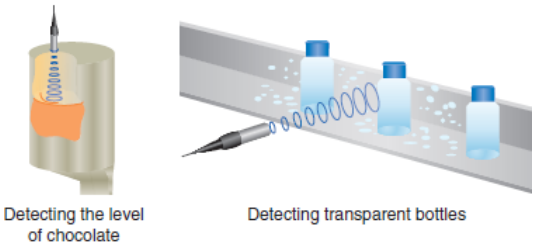


❑Sensors

Ultrasonic Sensors

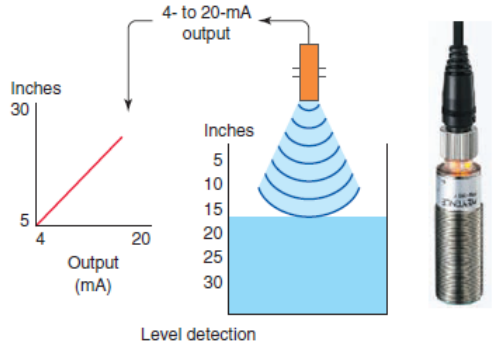
➢An *ultrasonic sensor operates by sending high-frequency* sound waves toward the target and measuring the time it takes for the pulses to bounce back.

➢The time taken for this echo to return to the sensor is directly proportional to the distance or height of the object because sound has a constant velocity.



Detecting the level of chocolate

Detecting transparent bottles



Level detection

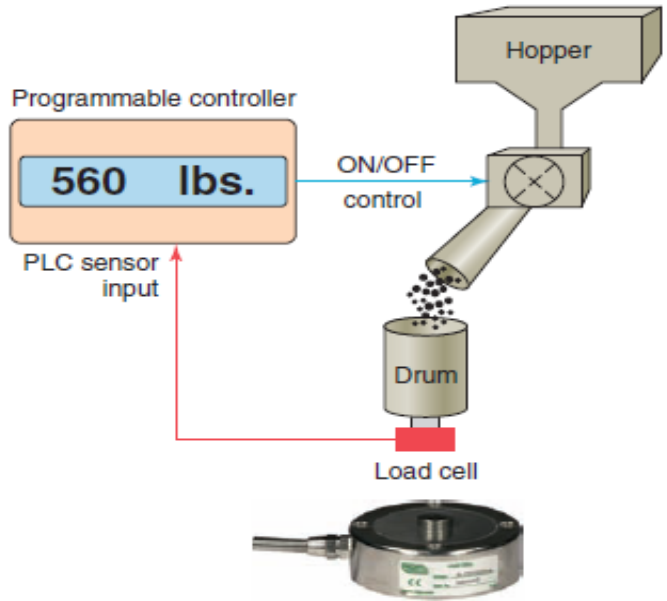
❑Sensors

Strain/Weight Sensors

➢A *strain gauge converts a mechanical strain into an electric* signal.

➢ Strain gauges are based on the principle that the resistance of a conductor varies with length and crosssectional area. The force applied to the gauge causes the gauge to bend.

➢This bending action also distorts the physical size of the gauge, which in turn changes its *resistance*

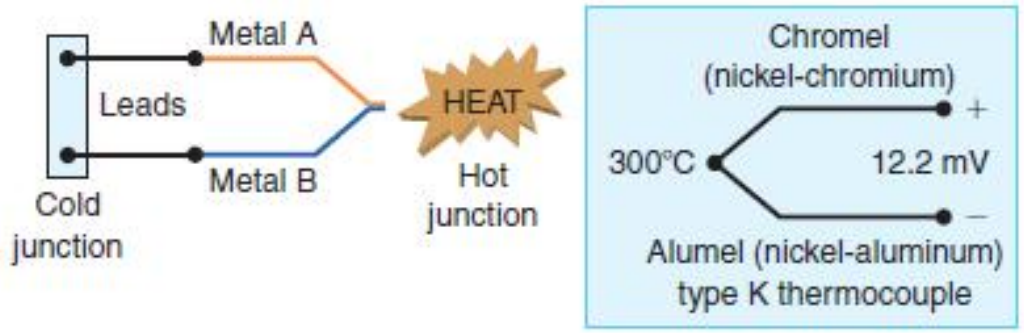


❑Sensors

Temperature Sensors

✓The thermocouple is the most widely used temperature sensor.

✓Thermocouples operate on the principle that when two dissimilar metals are joined, a predictable DC voltage will be generated that relates to the difference in temperature between the hot junction and the cold junction (Figure).



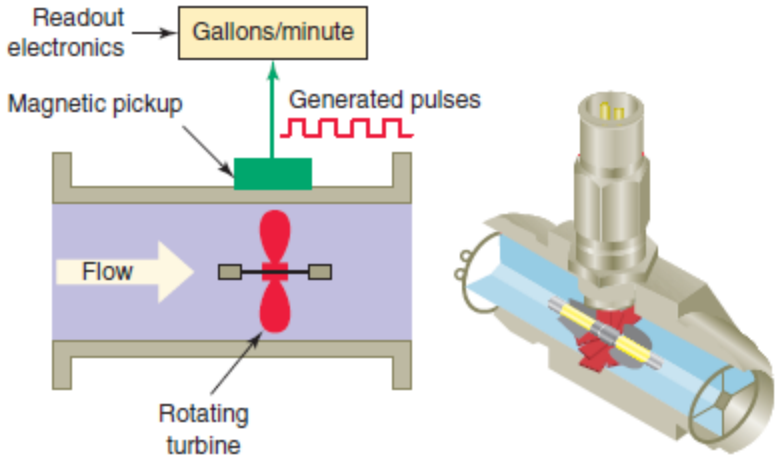
❑Sensors

Flow Measurement

➢Turbine flowmeters, like windmills, utilize their angular velocity (rotationspeed) to indicate the flow velocity.

➢The operation of a turbine flowmeter is illustrated in Figure .

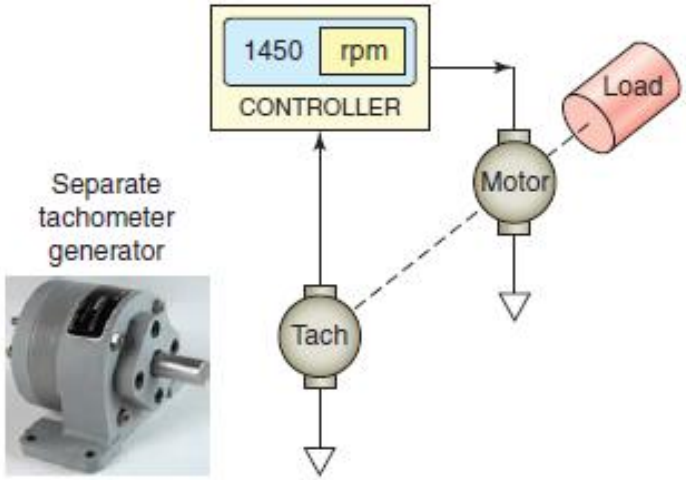
Its basic construction consists of a bladed turbine rotor installed in a flow tube.



❑Sensors

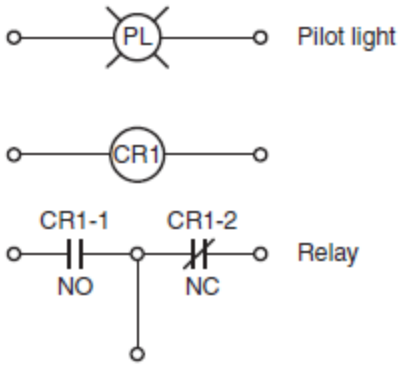
Velocity and Position Sensors

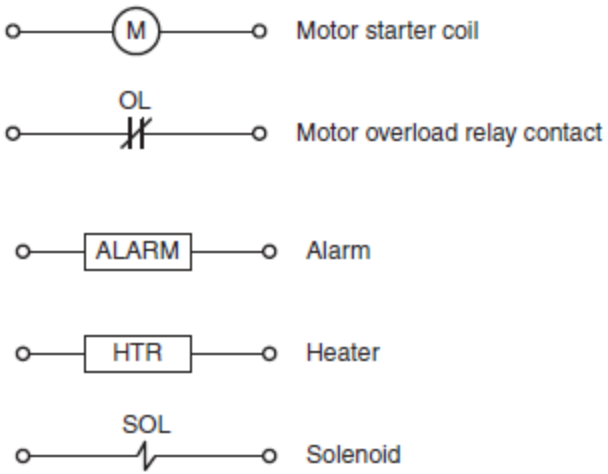
➢*Tachometer generators provide a convenient means of* converting rotational speed into an analogue voltage signal that can be used for motor speed indication and control applications.

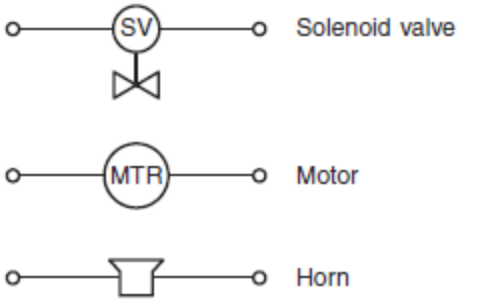


❑Output Control Devices

- ➢A variety of output control devices can be operated by the PLC output to control traditional industrial processes.
- ➢These devices include pilot lights, control relays, motor starters, alarms, heaters, solenoids, solenoid valves, small motors, and horns
- ➢Similar electrical symbols are used to represent these devices both on relay schematics and PLC output connection diagrams.
- ➢Figure shows common electrical symbols used







❑Output Control Devices

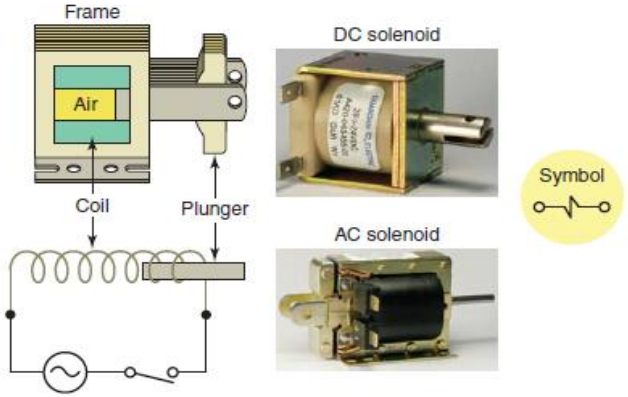
✓ Solenoid

➢An *actuator, in the electrical sense, is any device* that converts an electrical signal into mechanical movement.

➢An electromechanical solenoid is an actuator that uses electrical energy to magnetically cause mechanical control action.

➢ A solenoid consists of a coil, frame, and plunger (or armature, as it is sometimes called).

➢Figure shows the basic construction and operation of a solenoid.



❑Output Control Devices

➢Its operation can be summarized as follows:

• The coil and frame form the fixed part.

• When the coil is energized, it produces a magnetic field that attracts the plunger, pulling it into the frame and thus creating mechanical motion.

• When the coil is de-energized the plunger returns to its normal position through gravity or assistance from spring assemblies within the solenoid.

• The frame and plunger of an AC-operated solenoid are constructed with laminated pieces instead of a solid piece of iron to limit eddy currents induced by the magnetic field.

❑Output Control Devices

✓ Solenoid Valve

➢Solenoid valves are electromechanical devices that work by passing an electrical current through a solenoid, thereby changing the state of the valve.

➢Normally, there is a mechanical element, which is often a spring, that holds the valve in its default position.

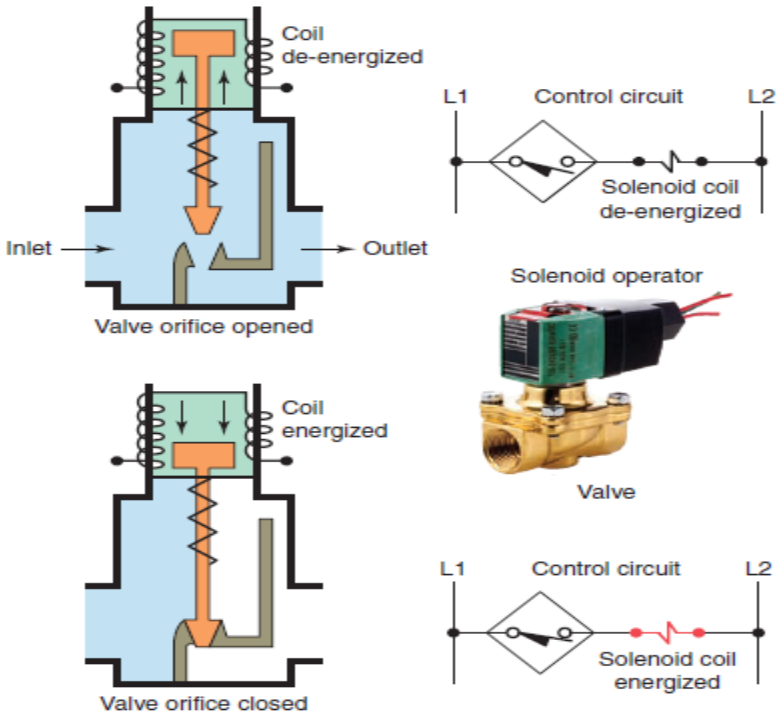
➢A solenoid valve is a combination of a solenoid coil operator and valve, which controls the flow of liquids, gases, steam, and other media. When electrically energized, they open, shut off, or direct the flow of media.

❑Output Control Devices

➢Figure illustrates the construction and principle of operation of a typical fluid solenoid valve.

• The valve body contains an orifice in which a disk or plug is positioned to restrict or allow flow.

• Flow through the orifice is either restricted or allowed depending on whether the solenoid coil is energized or de-energized.



❑Output Control Devices

✓ Stepper Motor

➢*Stepper motors operate differently than standard types,* which rotate continuously when voltage is applied to their terminals.

➢The shaft of a stepper motor rotates in discrete increments when electrical command pulses are applied to it in the proper sequence.

➢Every revolution is divided into a number of steps, and the motor must be sent a voltage pulse for each step.

➢The amount of rotation is directly proportional to the number of pulses, and the speed of rotation is relative to the frequency of those pulses.

➢Stepper systems are used most often in “open-loop” control systems, where the controller tells the motor only how many steps to move and how fast to move, but does not have any way of knowing what position the motor is at.

❑Output Control Devices

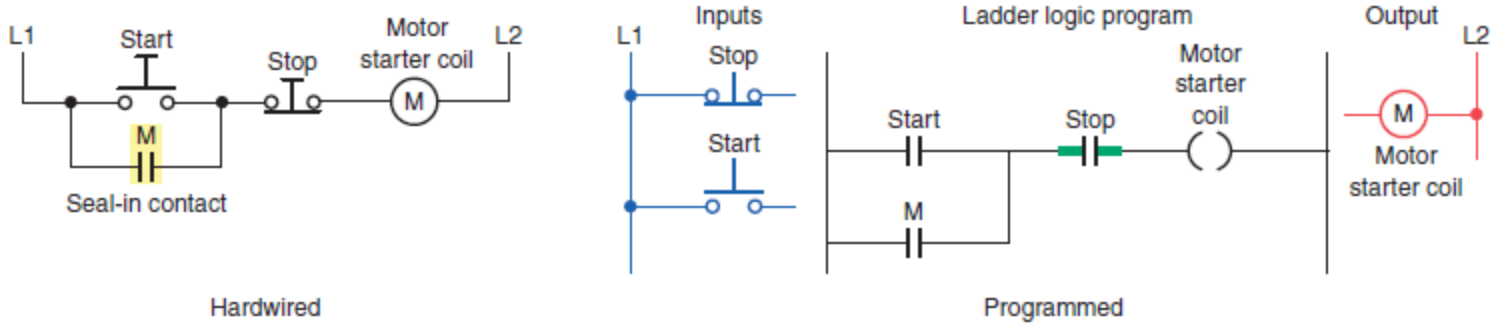
✓ Seal-In Circuits

➢*Seal-in, or holding, circuits are very common in both* relay logic and PLC logic.

➢Essentially, a seal-in circuit is a method of maintaining current flow after a momentary switch has been pressed and released.

➢In these types of circuits, the seal-in contact is usually in parallel with the momentary device.

➢The motor stop/start circuit shown in Figure is a typical example of a seal-in circuit.

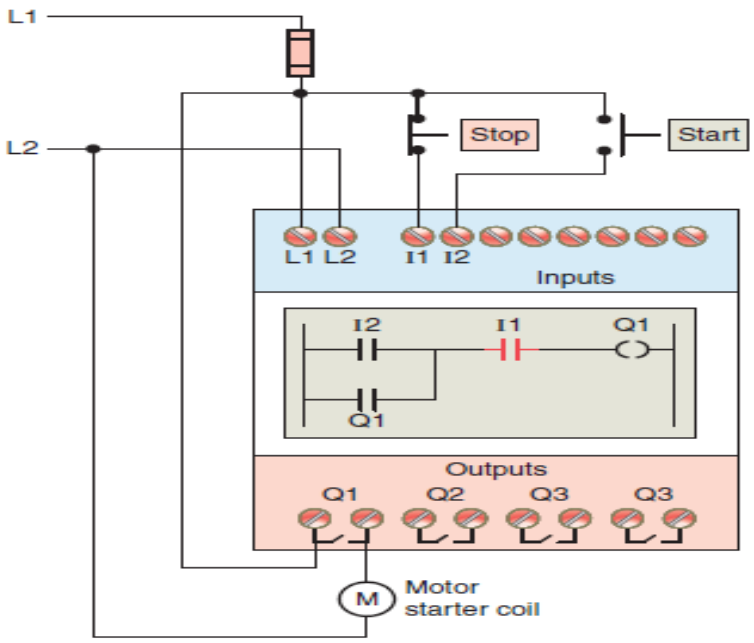


❑Output Control Devices

✓ Seal-In Circuits

➢The hardwired circuit consists of a normally closed stop button in series with a normally open start button.

➢The seal-in auxiliary contact of the starter is connected in parallel with the start button to keep the starter coil energized when the start button is released.



❑Output Control Devices

✓ Latching Relays

- Electromagnetic latching relays are designed to hold the relay closed after power has been removed from the coil.
- Latching relays are used where it is necessary for contacts to stay open and/or closed even though the coil is energized only momentarily.
- Figure shows a latching relay that uses two coils.
- The *latch coil is momentarily* energized to set the latch and hold the relay in the latched position.
- The *unlatch or release coil is momentarily* energized to disengage the mechanical latch and return the relay to the unlatched position.

❑Output Control Devices

✓ Latching Relays

➢shows a hardwired control circuit for an electromagnetic latching relay.

➢The operation of the circuit can be summarized as follows:

• The contact is shown with the relay in the *unlatched* position.

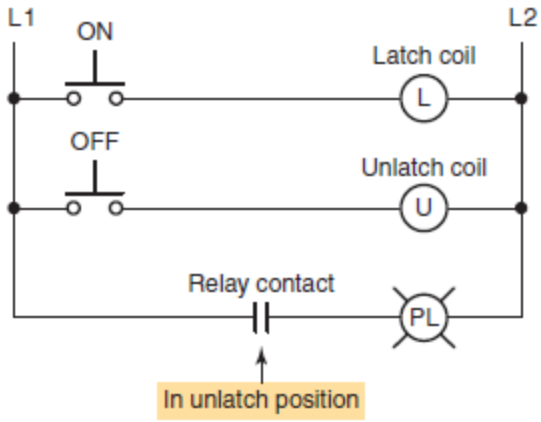
• In this state the circuit to the pilot light is open and so the light is off.

• When the ON button is *momentarily actuated, the* latch coil is energized to set the relay to its latched position.

• The contacts close, completing the circuit to the pilot light, and so the light is switched on.

• The relay coil does *not have to be continuously* energized to hold the contacts closed and keep The light on.

•



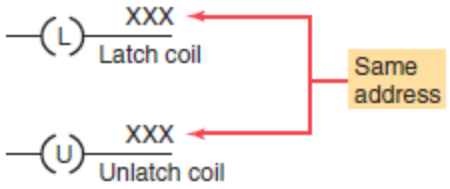
❑Output Control Devices

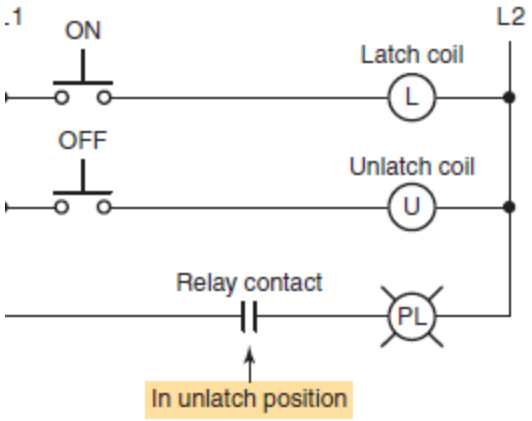
✓ Latching Relays

• The only way to switch the lamp off is to actuate the OFF button, which will energize the unlatch coil and return the contacts to their open, unlatched state.

• In cases of power loss, the relay will remain in its original latched or unlatched state when power is restored.

Command	Name	Symbol	Description
OTL	Output latch	(L)	OTL sets the bit to "1" when the rung becomes true and retains its state when the rung loses continuity or a power cycle occurs.
OTU	Output unlatch	(U)	OTU resets the bit to "0" when the rung becomes true and retains it.





❑Output Control Devices

✓ Latching Relays

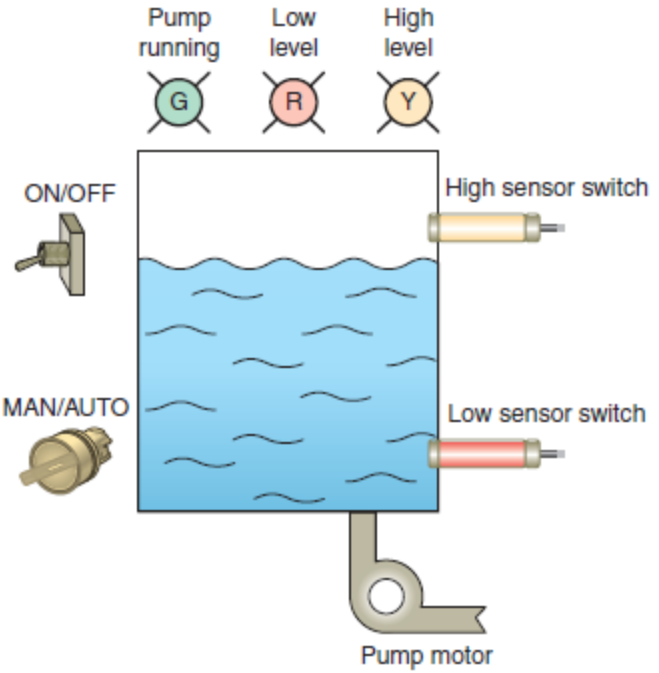
• The process shown in Figure is to be used to control the level of water in a storage tank by turning a discharge pump on or off.

The modes of operation are to be programmed as follows:

OFF Position —The water pump will *stop if it is running* and will *not start if it is stopped.*

Manual Mode —The pump will start if the water in the tank is at any level except low.

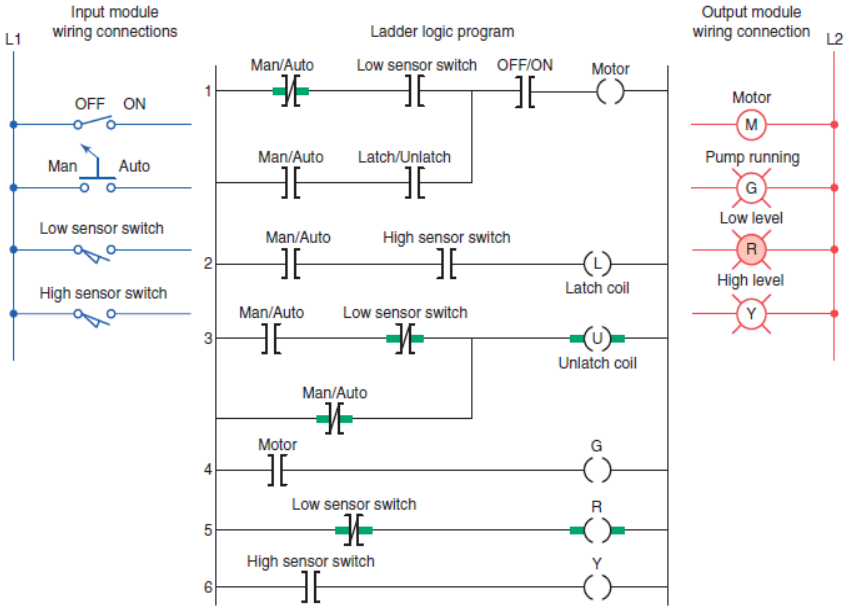
Automatic Mode —If the level of water in the tank *reaches a high point, the water pump will start so that* water can be removed from the tank, thus lowering the level.



❑Output Control Devices

✓ Latching Relays

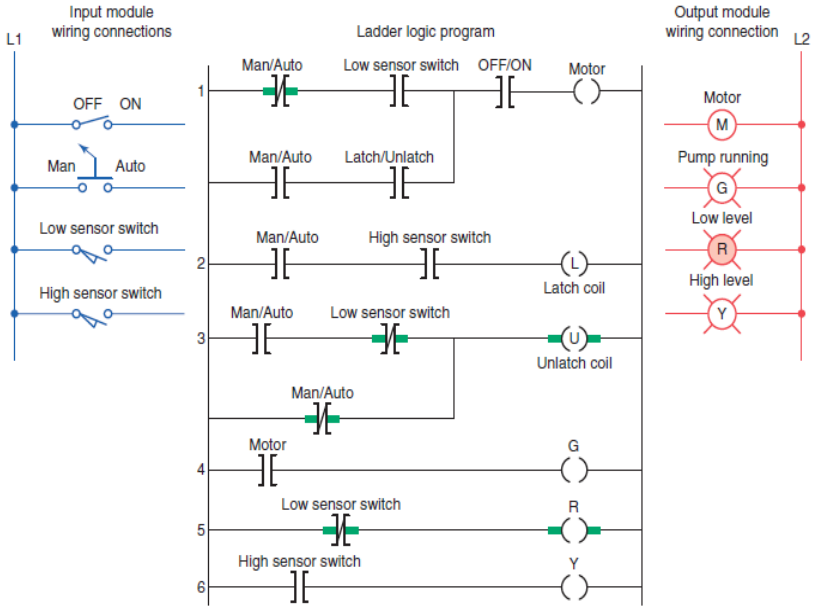
- The rung 1 Examine-on instruction addressed to the off/on switch prevents the pump motor from starting under any condition when in the off (open) state.
- In the MAN mode, the rung 1 Examine-on instruction addressed to the low sensor switch allows the pump motor to operate only when the low level sensor switch is closed.
- In the AUTO mode, whenever the high sensor switch is momentarily closed the Examine-on instruction of rung 1 addressed to it will energize the latch coil.



❑Output Control Devices

✓ Latching Relays

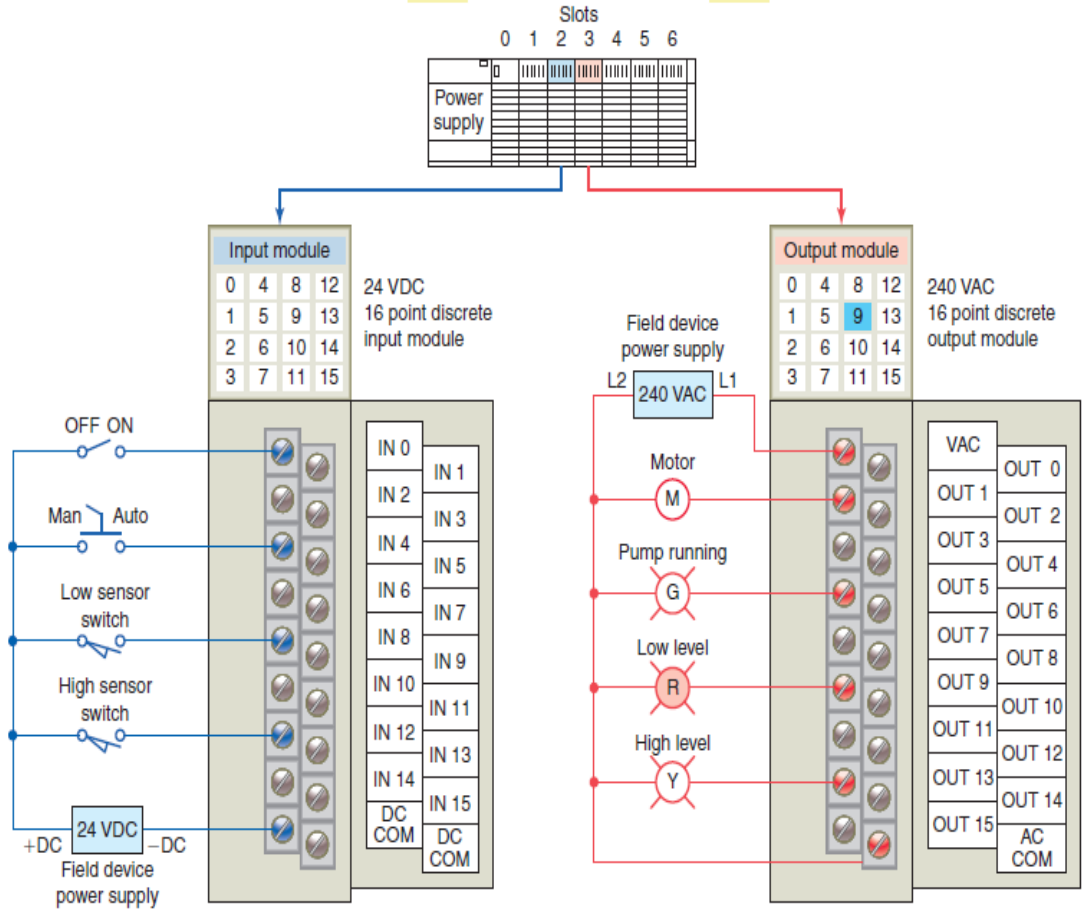
- The pump will begin running and continue to operate until the unlatch coil is energized by the rung 3 Examine-off instruction addressed to the low sensor switch.
- The pump running status light is controlled by the rung 4 Examine-on instruction addressed to the motor output.
- The low level status light is controlled by the rung 5 Examine-off instruction addressed to the low sensor switch.
- The high level status light is controlled by the rung 6 Examine-on instruction addressed to the high sensor switch.

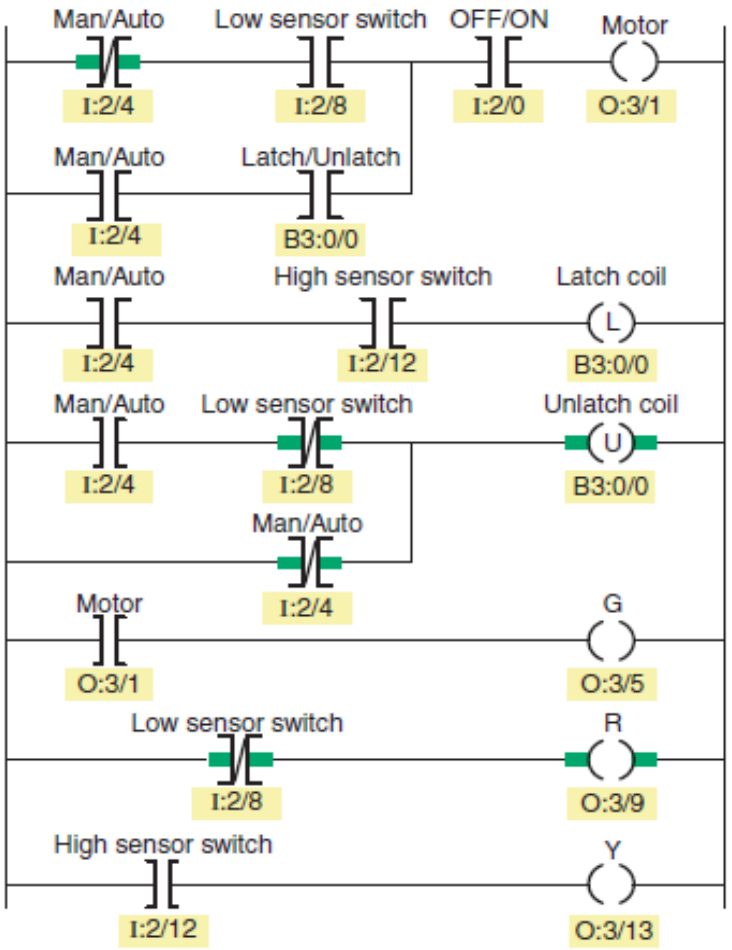


❑Output Control Devices

✓ Latching Relays

. Figure shows a typical I/O module wiring diagram





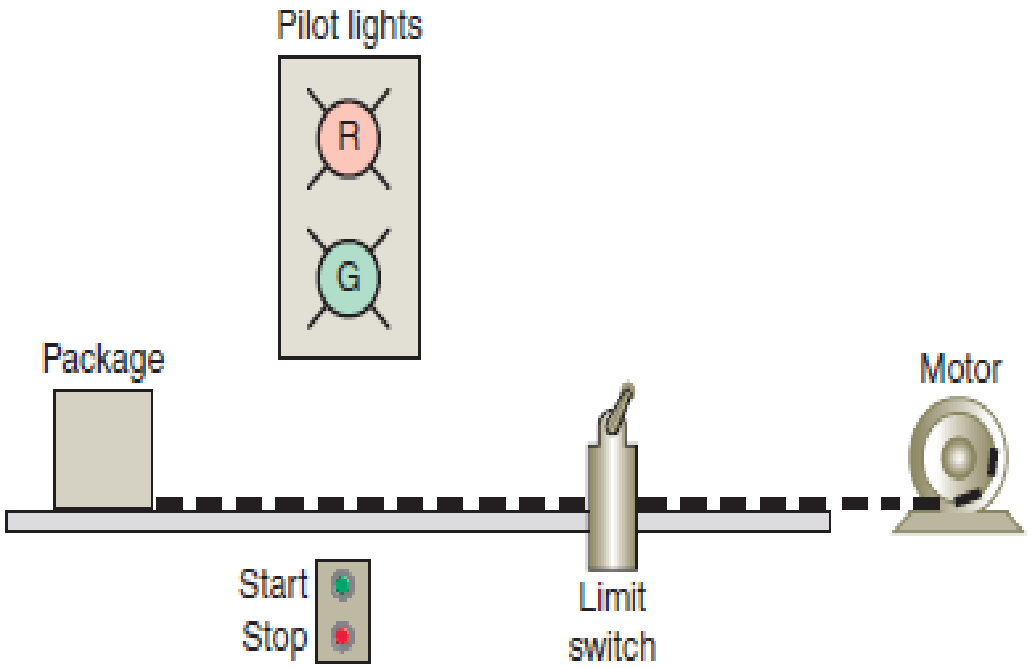
❑Converting Relay Schematics into PLC Ladder Programs

Figure shows the sequential process flow diagram which is asfollows:

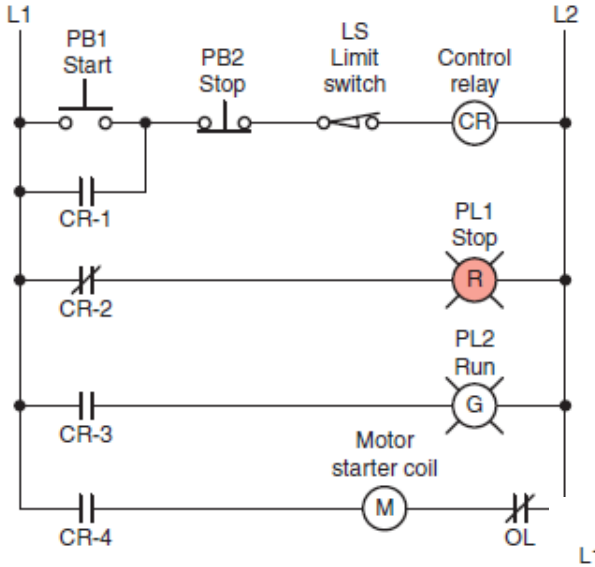
1. Start button is pressed.
2. Table motor is started.
3. Package moves to the position of the limit switch and automatically stops.

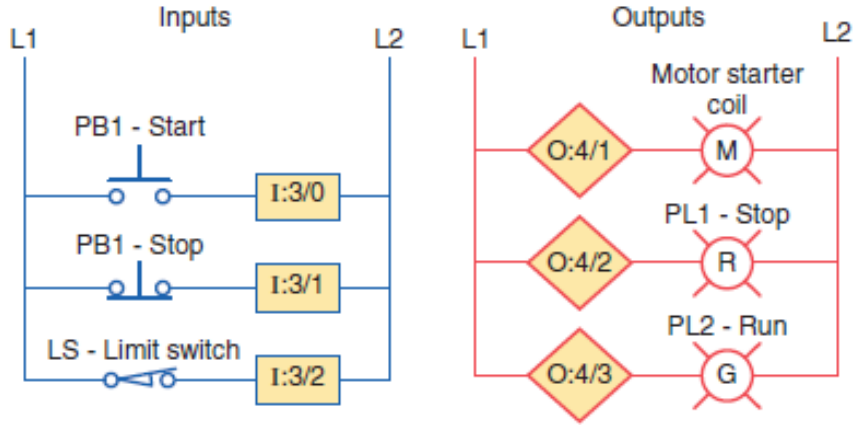
Other auxiliary features include:

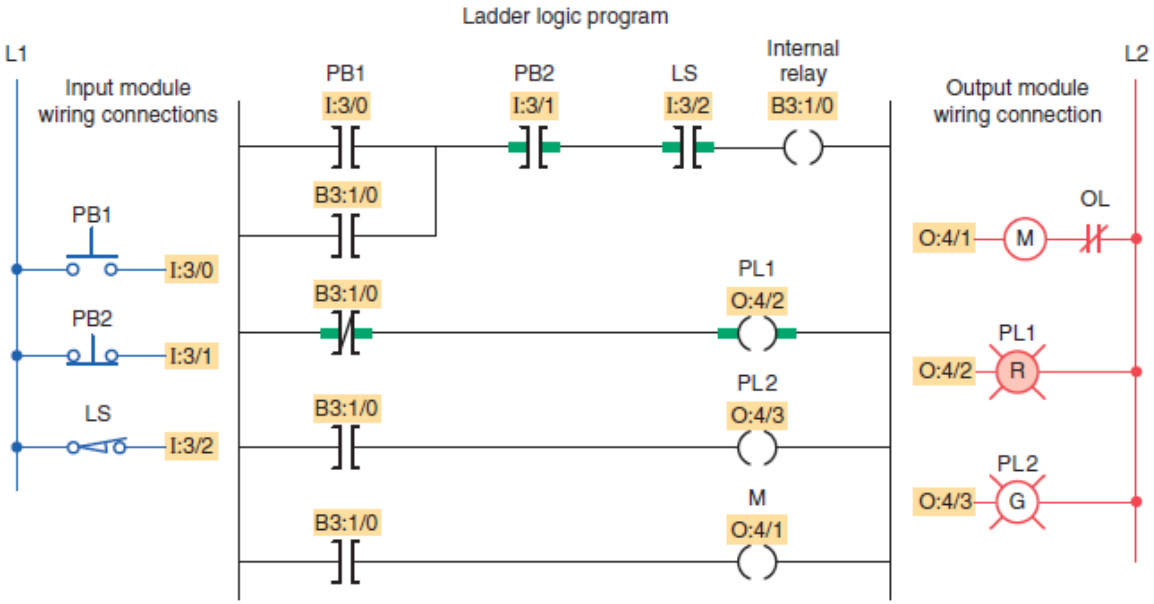
- A stop button that will stop the table, for any reason, before the package reaches the limit switch position
- A red pilot light to indicate the table is stopped
- A green pilot light to indicate the table is running



❑Converting Relay Schematics into PLC Ladder Programs

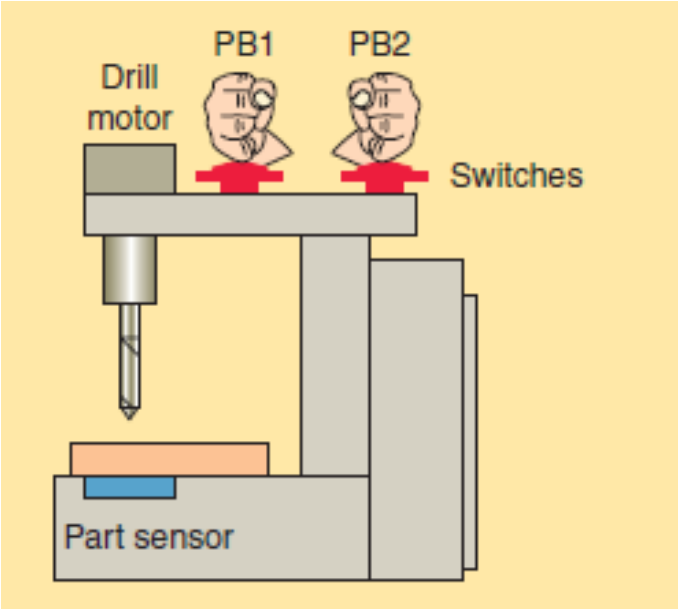




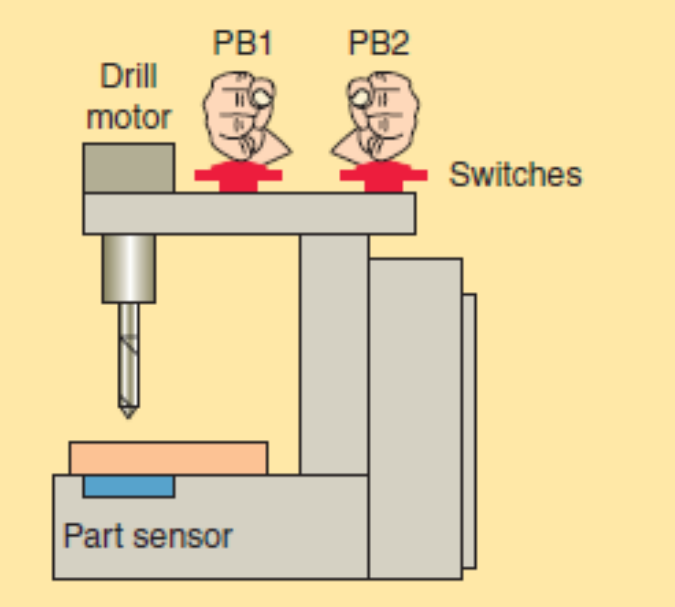


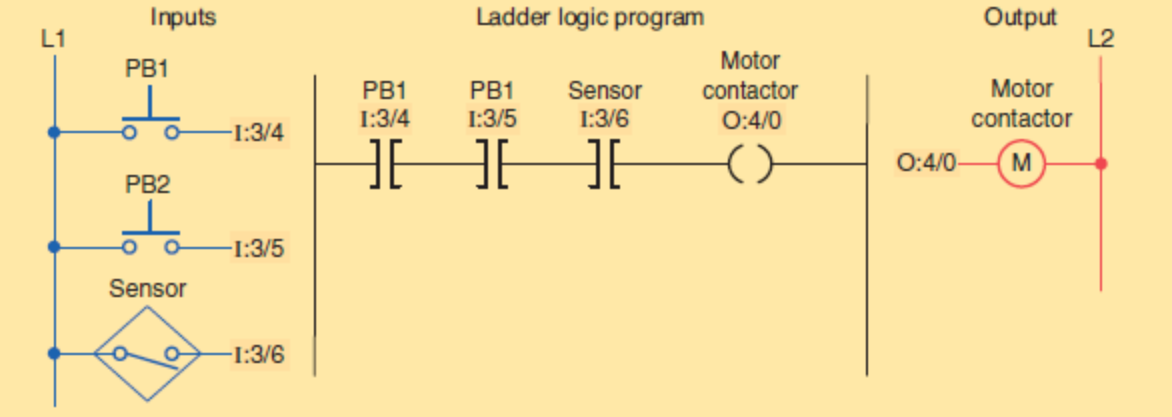
❑Writing a Ladder Logic Program Directly from a Narrative Description

✓Figure shows the sketch of a drilling process that requires the drill press to turn on only if there is a part present and the operator has one hand on each of the start switches. This precaution will ensure that the operator's hands are not in the way of the drill. The sequence of operation requires that switches 1 and 2 and the part sensor all be activated to make the drill motor operate.



❑Writing a Ladder Logic Program Directly from a Narrative Description

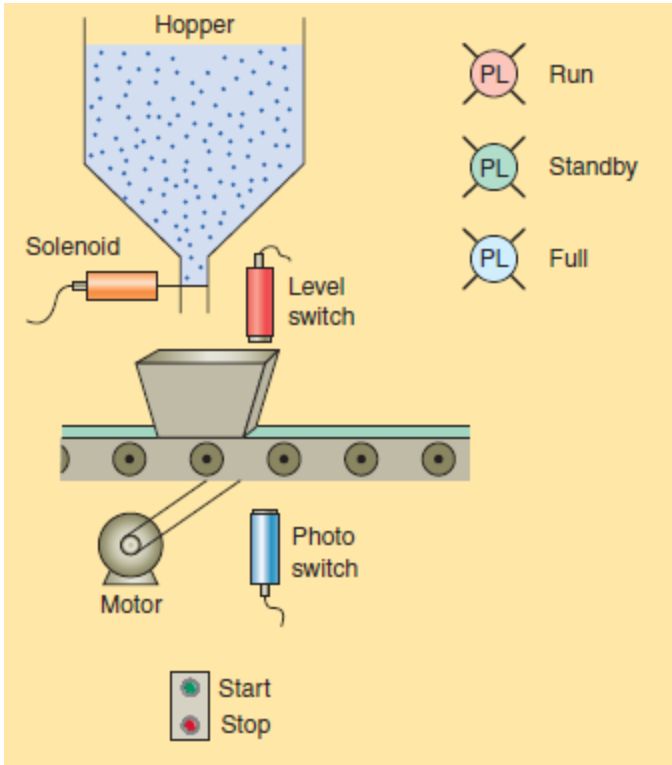




❑Writing a Ladder Logic Program Directly from a Narrative Description

Figure shows the sketch of a continuous filling operation. This process requires that boxes moving on a conveyor be automatically positioned and filled. The sequence of operation for the continuous filling operation is as follows:

- Start the conveyor when the start button is momentarily pressed.
- Stop the conveyor when the stop button is momentarily pressed.
- Energize the run status light when the process is operating.
- Energize the standby status light when the process is stopped.
- Stop the conveyor when the right edge of the box is first sensed by the photosensor.
- With the box in position and the conveyor stopped, open the solenoid valve and allow the box to fill. Filling should stop when the level sensor goes true.
- Energize the full light when the box is full. The full light should remain energized until the box is moved clear of the photosensor.



❑Writing a Ladder Logic Program Directly from a Narrative Description