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Sensors

Sensors

Industrial Maintenance
LabVolt Series
Student Manual

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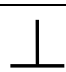
Safety and Common Symbols

The following safety and common symbols may be used in this manual and on the equipment:

Symbol	Description
⚠ DANGER	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
⚠ WARNING	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
⚠ CAUTION	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger* sign ⚠, indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger
	Caution, lifting hazard
	Caution, hand entanglement hazard
	Notice, non-ionizing radiation
	Direct current
	Alternating current
	Both direct and alternating current
	Three-phase alternating current
	Earth (ground) terminal

Safety and Common Symbols

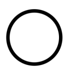
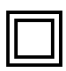
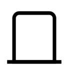
Symbol	Description
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

Table of Contents

Table of Contents

Table of Contents

Table of Contents

Preface

The Sensors Training System, Model 8036-4, introduces the use of sensors.

The Sensors Training System is part of the Industrial Controls Training Program, which includes the following systems:

- Basic Controls;
- Programmable Logic Controller;
- Motor Drives;
- Sensors.

We hope that your learning experience will be the first step of a successful career.

We invite readers of this manual to send us their tips, feedback, and suggestions for improving the book.

Please send these to did@de.festo.com.

The authors and Festo Didactic look forward to your comments.

About This Manual

The exercises in this manual, *Sensors,* complement the exercises contained in the manuals *Basic Controls,* and *Programmable Logic Controller.*

Each exercise is divided into the following :

- A clearly defined Exercise Objective;
- A Discussion of the theory involved in the exercise;
- A Procedure Summary which provides a bridge between the theoretical Discussion and the laboratory Procedure;
- A step-by-step laboratory Procedure where important principles covered in the Discussion are observed and quantified;
- A Conclusion to summarize the material presented in the exercise;
- Review Questions to verify that the material has been well assimilated.

Optional equipment

Exercises 7 and 8 require the use of the optional Reversible AC Motor.

Safety considerations

Safety symbols that may be used in this manual and on the equipment are listed in the Safety Symbols table at the beginning of the manual.

Safety procedures related to the tasks that you will be asked to perform are indicated in each exercise.

Make sure that you are wearing appropriate protective equipment when performing the tasks. You should never perform a task if you have any reason to think that a manipulation could be dangerous for you or your teammates.

Reference material

Refer to the component data sheets for detailed information on how to use the devices. These data sheets are included on the CD supplied with the manual *Basic Controls*, Model 39163 (or 87774).

Prerequisite

To perform the exercises in this manual, you should have completed the manual *Basic Controls*, Model 39163 (or 87774). You should have also completed the manual *Programmable Logic Controller*, Model 39436, to perform Exercise 8.

About This Manual

Systems of units

Units are expressed using the International System of Units (SI) followed by the units expressed in the U.S. customary system of units (between parentheses).

Introduction to Sensors

EXERCISE OBJECTIVE

- Introduce photoelectric, proximity and limit switches;
- Learn the terms commonly used in the sensor field;
- Become familair with the components of the Sensors Training System.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Photoelectric sensors
- Capacitive and inductive proximity sensors
- Excess gain ratio
- Hysteresis
- Switching frequency
- Sensor output types
  Transistor output. Relay output. Sensor selection guide.

DISCUSSION

Sensor controls perform many functions in automated manufacturing and material handling systems. They are used for counting, positioning, determining product orientation, sorting, monitoring and measuring productivity, quality assurance, and much more. Sensors respond to the presence or absence of virtually any type of object – large or small, transparent or opaque, shiny or dull.

They are divided into two large categories: contact and non-contact. Contact sensors require a physical contact with the target to be triggered, while non-contact sensors can sense the target without touching it, as long as the target is within the sensing range.

Photoelectric sensors

Photoelectric sensors can detect the presence or absence of virtually any type of object without any physical contact. Therefore, they can satisfy a wide range of control needs. Figure 1 shows a typical photoelectric application.

Photoelectric sensors use a light beam to sense the presence or motion of an object. They consist of a light emitter and a light receiver. The emitter is a light emitting diode (LED) that emits a specific wavelength of light. Infrared, visible red, green and blue are used as the light source in most photoelectric sensors. Infrared LEDs are used where maximum light output is required for an extended sensing range. In some applications, a visible light beam is used to ease the setup or confirm sensor operation. Visible and infrared lights are tiny parts of the electromagnetic spectrum shown in Appendix E.

The receiver is a photodiode or phototransistor that provides a change in conducted current, depending on how much light is detected. Photodiodes and phototransistors are more sensitive to certain wavelengths of light. To improve efficiency, the light emitter and receiver must be spectrally matched.

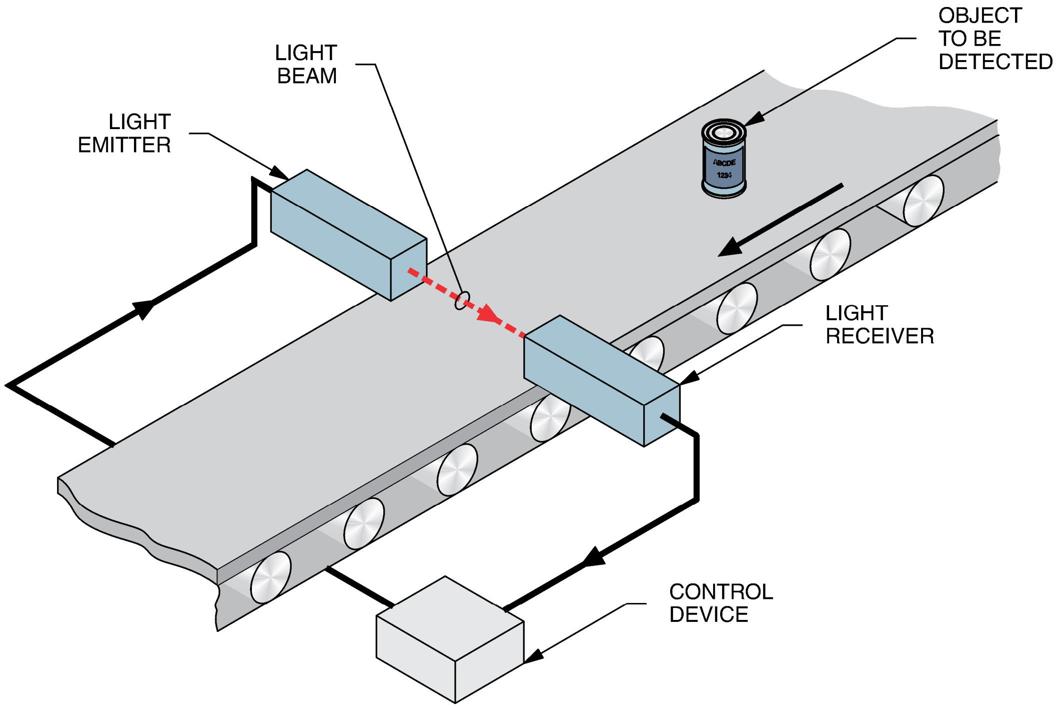


Figure 1. Typical photoelectric application.

Unwanted effects of stray light on sensor operation can be reduced by modulating the frequency of the light beam. If the light beam was not frequency modulated, bright light from direct sunlight could be detected by the receiver and give false indications. When the receiver senses a modulated light beam, it converts the light impulses to electrical impulses. Light beam modulation is achieved by switching the LED on and off. Furthermore, this operation mode allows the current and therefore the amount of emitted light to exceed what would be allowable under continuous operation.

There are two ways of detecting the light beam: light sensing and dark sensing. Light sensing means the receiver detects the presence of the light beam. The receiver does not provide an output signal until it detects the light beam. Dark sensing means the receiver detects the absence of the light beam.

There are three types of photoelectric sensing modes: diffuse-reflective, through-beam, and retroreflective. Figure 2 shows how each mode works.

In the diffuse-reflective sensing mode, shown in Figure 2 (a), the emitter and receiver are contained in the same housing. The emitter projects a light beam, and when a target object enters the beam, light reflects off the object back to the receiver. The primary advantage of a diffuse-reflective sensor is its simplicity – it is self-contained and needs no reflector.

In the through-beam sensing mode, shown in Figure 2 (b), the emitter and receiver are contained in separate housings. The emitter projects a light beam directly toward the receiver. The target object interrupts the beam and the receiver senses the absence of the light beam (presence of an object). Through-beam sensors provide long sensing distances [more than 250 m (820 ft)]. These sensors are well suited to operate in very dusty or dirty industrial environments, but may not be suitable to detect translucent or transparent targets since the receiver may see through this type of target.

In the retroreflective sensing mode, as shown in Figure 2 (c), the emitter and receiver are contained in the same housing. The emitter projects a light beam toward a reflector, which directs the beam back to the receiver. The presence of a target object interrupts the reflected light beam and the receiver senses the absence of the light beam.

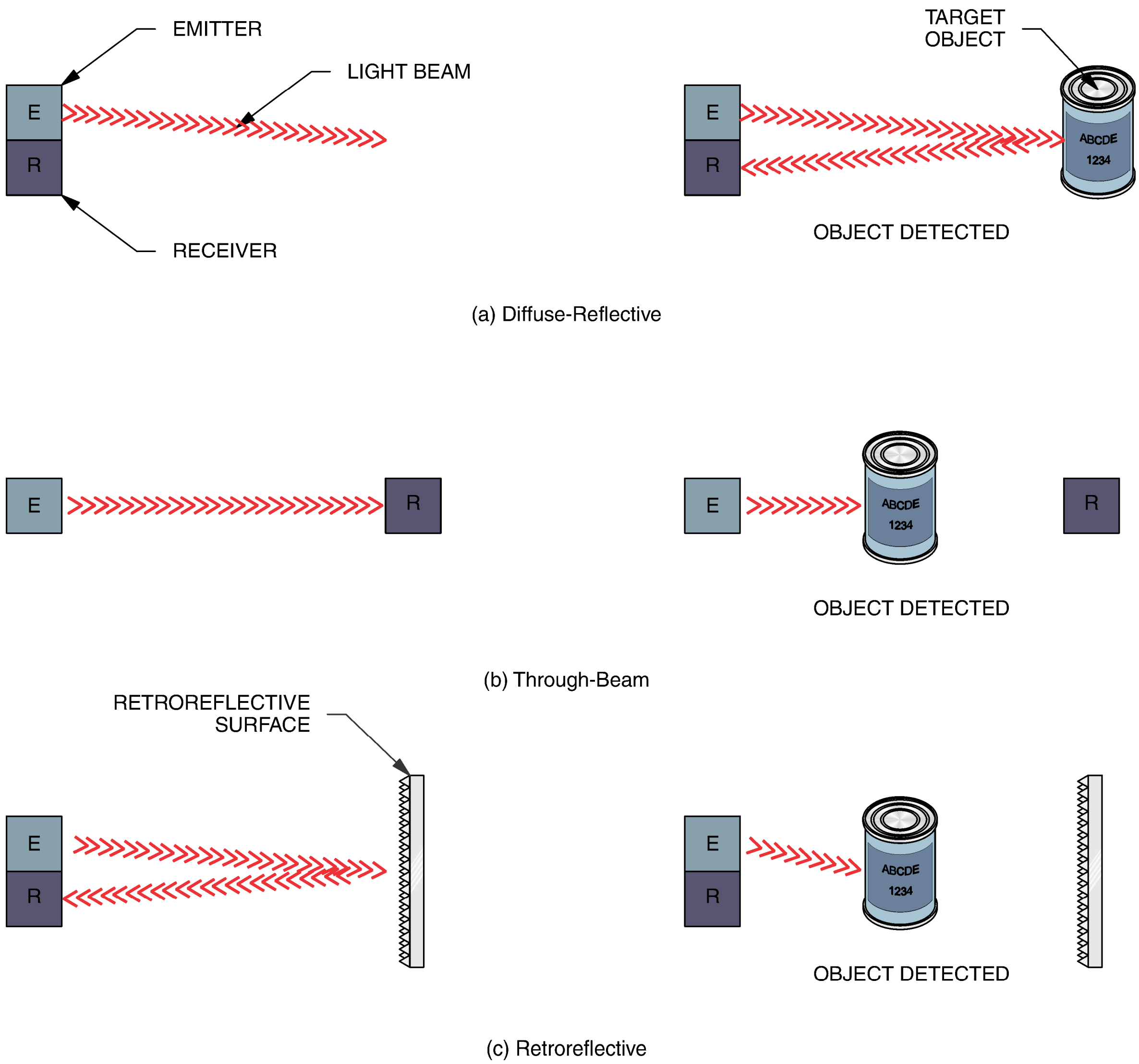


Figure 2. Photoelectric sensing modes.

Capacitive and inductive proximity sensors

As photoelectric sensors, capacitive and inductive proximity sensors detect the presence or absence of objects without any physical contact. Capacitive sensors detect both metallic and nonmetallic objects, while inductive sensors detect the presence of metallic objects only. The term proximity indicates that these sensorsprovide only short sensing distance.

Excess gain ratio

The excess gain ratio, also called operating margin or margin, is the ratio of light intensity available at a given distance of a sensor to the light intensity needed to trigger the sensor. An excess gain ratio of one is obtained when just enough light is detected to switch the state of the sensor output. An excess gain ratio of 10 is obtained when 10 times the minimum light level required to switch the state of the sensor output is detected.

Excess gain is the extra light energy that is available to overcome attenuation caused by dirt, dust, smoke, moisture, or other contaminants in the scanned environment.

Hysteresis

Hysteresis is the difference between the "operating point" (where a detected target causes the sensor output to switch to the activated mode) and the "releasing point" (where a target is no longer detected and the sensor output switches to the deactivated mode). Hysteresis is needed to help prevent chattering (turning on and off rapidly) when the sensor is subjected to shocks and vibrations, or when the target is stationary at the nominal sensing distance. Vibration amplitudes must be smaller than the hysteresis band to avoid chattering.

Switching frequency

The switching frequency is the maximum number of switching operations per second. It corresponds to the speed at which a sensor can deliver discrete individual pulses as the target enters and leaves the sensing field. This value depends on the target size, distance from sensing face, speed of target, and switch type. Some manufacturers express the sensor speed in terms of response time T (T = 1/f).

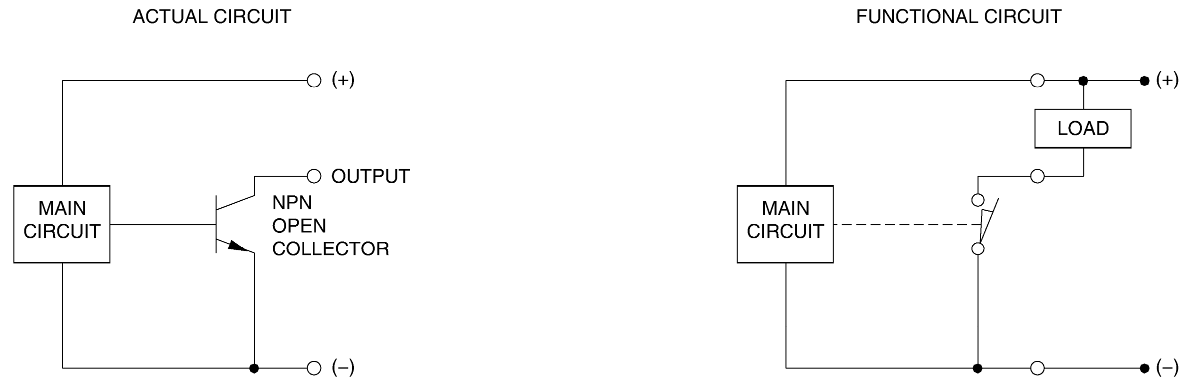
Sensor output types

The sensors of your training system are identified by their sensing mode followed by the term "switch." This term refers to the sensor output that switches "on" or "off" depending on the presence, or absence, of a target. The sensors act as switches activated by targets, rather than transducers whose output is proportional to an input signal.

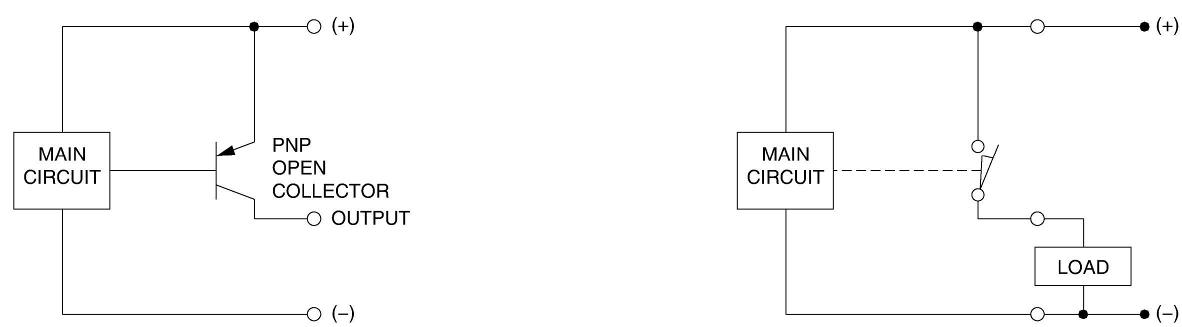
Transistor output

The transistor is the typical solid-state output device for low voltage DC sensors. There are two output types: sinking and sourcing.

Sinking transistor output requires the load to be connected between the sensor output and the positive power connection, as shown in Figure 3 (a). A current sink output requires an NPN transistor. This output configuration can directly operate low-voltage logic circuitry (as transistor-transistor logic, TTL).



(a) Sinking Output



(b) Sourcing Output

Figure 3. Transistor output.

Sourcing transistor output requires the load to be connected between the sensor output and the negative power connection as shown in Figure 3 (b). A current source output requires a PNP transistor. This output configuration produces a logic zero, or false, when the sensor is not activated. Therefore, this output configuration is commonly used as PLC input.

Relay output

Because the maximum output current of output transistors is low (≈100 mA), a coil operating a set of normally-open (NO) and normally-closed (NC) contacts is often connected at the transistor output, as shown in Figure 4. This is the case for the sensors of your training system.

When the sensor is in the activated mode, current flows through the relay coil (CR). This causes the relay contacts to switch to the activated mode. Relay contacts can control the operation of important AC and DC loads. Because relays are mechanical devices, they can add 10 to 25 ms to the response time of a sensor.

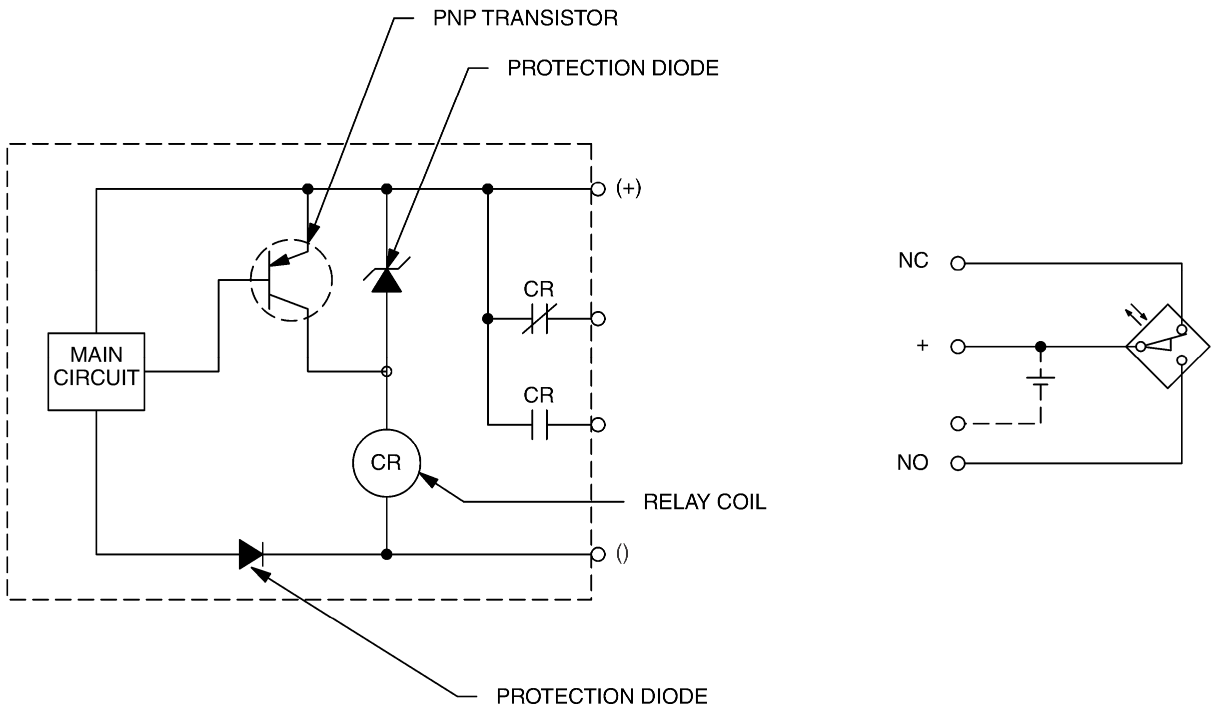


Figure 4. Relay output.

Sensor selection guide

A Sensor Selection Guide is supplied in Appendix B. It shows some parameters that must be considered when selecting a sensor.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Set up and connections
- Equipment required
- Photoelectric switches
- Characteristics of the reflective block
- Switch operation

PROCEDURE

Set up and connections

In the first part of the exercise, you will determine if the photoelectric switches of the training system use visible red light or infrared light as a light source.

In the second part, you will determine the characteristics of the Reflective Block.

In the third part, you will observe how switches operate. You will observe that the normally closed contacts become normally open contacts when the sensor output switches to the activated mode.

Equipment required

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required to perform this exercise.

Photoelectric switches

1. There are two photoelectric switches in your Sensors Training System: the Background Suppression Photoelectric Switch, model 6373-B, and the Polarized Retroreflective Photoelectric Switch, model 6374-B.

Connect the sensors, one after another, as shown in Figure 5.

For each sensor, perform the Energizing procedure described in Appendix C of this manual.

Determine if these sensors use a visible red light beam or an infrared light beam by passing a finger at a distance of 25 mm (1 in) in front of the sensor. Observe if you can see a red point appearing on your finger. Note your observations in Table 1.

Infrared light is invisible and harmless to the human eye.

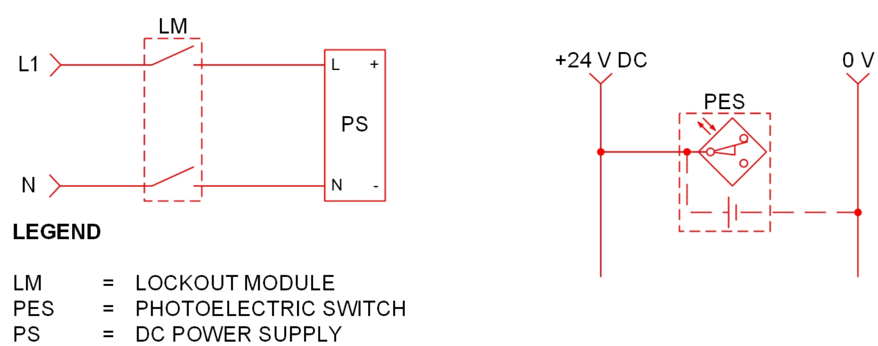


Figure 5. Circuit used to determine if the sensors use a visible or infrared light beam.

Table 1. Visible red and infrared light beams.

Photoelectric sensors	Visible red	Infrared
Background Suppression Photoelectric Switch, Model 6373		
Polarized Retroflective Photoelectric Switch, Model 6374		

2. Turn off the Lockout Module.

Characteristics of the reflective block

3. Get the Reflective Block, Model 6396. The Reflective Block has five different types of surfaces that will be used to determine the characteristics of the sensors. Associate the four following surface types to the surfaces shown in Figure 6.

Black Plastic

Shiny Metallic Surface

Matte Black Metallic Surface

White Plastic Surface

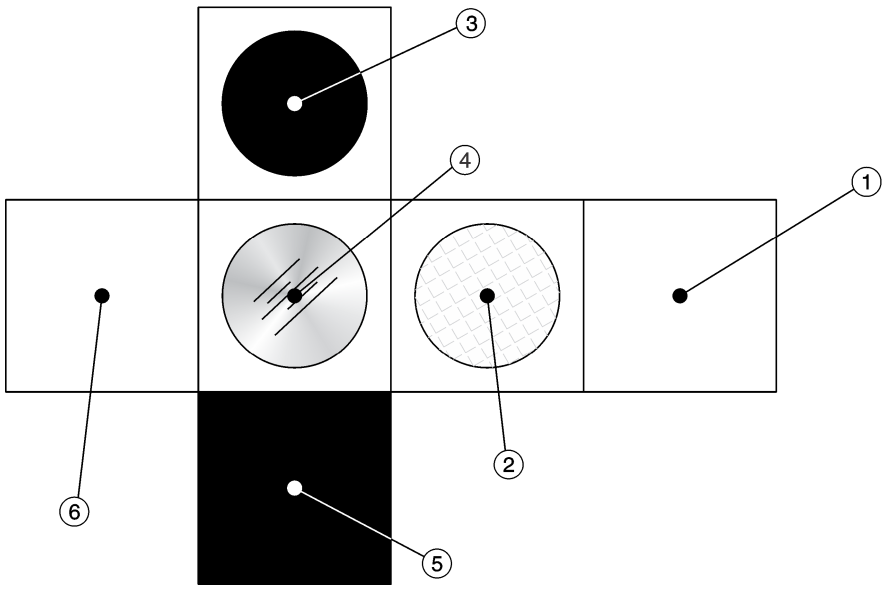


Figure 6. Development view of the Reflective Block

1 - Underside	4 -
2 - Depolarizing retroreflective surface	5 -
3 -	6 -

Switch operation

4. Connect the Capacitive Proximity Switch, Model 6376-B, as shown in Figure 7.

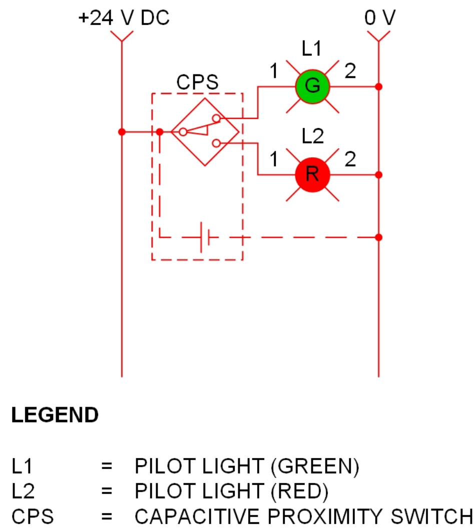


Figure 7. Circuit using the Capacitive Proximity Switch.

5. Turn on the Lockout Module.

There should not be any objects within 100 mm (4 in) in front of the sensor.

6. Is the green pilot light turned on, suggesting the Capacitor Proximity Switch is not triggered?

❑ Yes ❑ No

7. Move a finger back and forth about 6 mm (0.25 in) in front of the sensor. Does the red pilot light turn on when the finger is in front of the sensor? Explain why.

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8. What happens to the green pilot light when the red pilot light turns on?

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9. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you were introduced to sensors. You learned the terms commonly used in the sensor field, and you familiarized yourself with the components of the Sensors Training System.

You determined if the photoelectric switches of your training system use visible red light or infrared light as light source.

You observed the different surfaces that characterize the Reflective Block.

You also observed how the normally closed contacts of a switch become normally open contacts when the sensor output switches to the activated mode.

REVIEW QUESTIONS

1. How do photoelectric sensors detect the presence of objects?

2. What is the difference between light sensing and dark sensing?

3. What are the three types of photoelectric sensing modes?

4. What is meant by excess gain ratio when describing photoelectric switches?

5. What is meant by hysteresis when describing proximity switches?

Background Suppression Photoelectric Switch

EXERCISE OBJECTIVE

- Introduce the Background Suppression Photoelectric Switch;
- Become familiar with its operation using the Reflective Block.

DISCUSSION

Background suppression sensors are designed for short range applications where the background behind the target is very close and very reflective. Background suppression sensing is one of the many types of the diffuse sensing mode.

Instead of attempting to ignore the background behind the target, background suppression sensors actively use sophisticated electronics to detect the presence of both the target and the background.

Background suppression sensors contain two active photoelectric sensing elements calibrated to detect objects in front and behind the nominal sensing distance. As Figure 8 shows, sensing element 1 detects reflections from behind the nominal sensing distance, and sensing element 2 detects reflections in front of the nominal sensing distance.

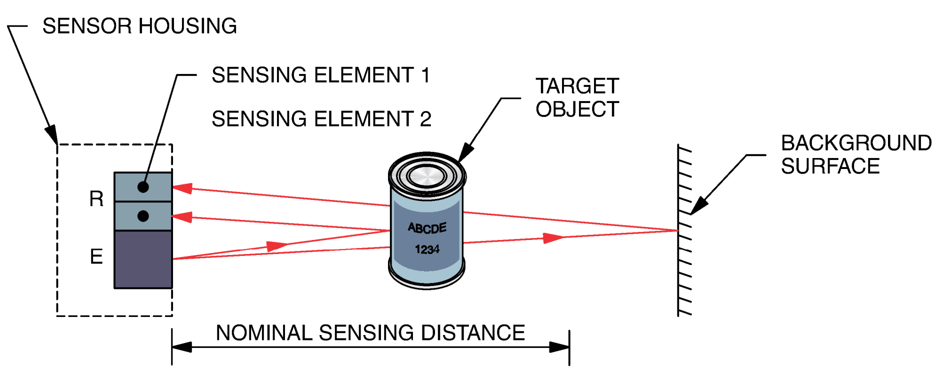


Figure 8. Background suppression sensing.

By comparing the two signals, the sensor can ignore the presence of a very reflective background almost directly behind a dark, less-reflective target. The sensor output will change state on active detection of the target, or on active detection of the background.

For reliable background suppression, a minimum separation distance of 10% of the maximum sensing distance is recommended between the target object and the background.

Due to the detection method, only targets traveling horizontally to the sensor are detected, that is from left to right or front to back, as shown in Figure 9. Targets traveling vertically may not be accurately detected.

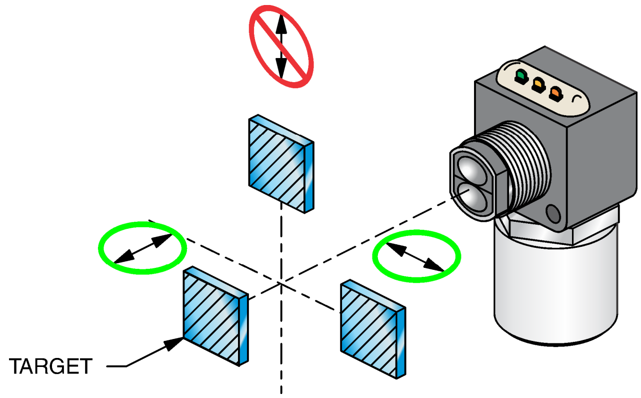


Figure 9. Detection method.

The Background Suppression Photoelectric Switch of your training system is shown in Figure 10. The sensor has a power indicator (green LED), an output indicator (yellow LED) that lights when the output is activated, and a stability indicator (orange LED) that lights when the excess gain exceeds 2.5. There is no sensitivity adjustment on this sensor. Other characteristics of the Background Suppression Photoelectric Switch are shown in Table 2.

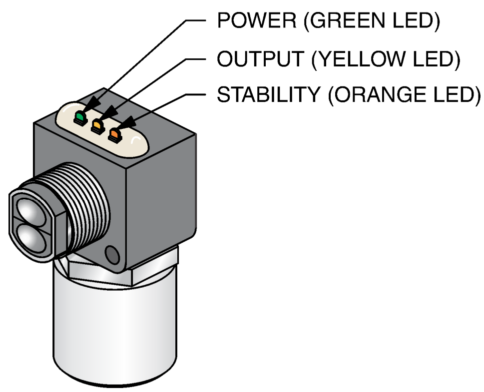


Figure 10. Background Suppression Photoelectric Switch.

Table 2. Characteristics of the Background Suppression Photoelectric Switch.

Background suppression photoelectric switch	
Type	Background suppression
Transistor output type	Sourcing (PNP)
Sensing distance	100 mm (3.9 in)
Light source Type Wavelength	Infrared 880 nm (34.6 micro-inch)
Response time (sensor only)	1.0 ms
Light beam detection modes	Light operate/Dark operate (1)

(1) The sensor has light operate and dark operate outputs. The output relay coil is connected to the light operate output. The dark operate output is not used.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Set up and connections
- Equipment required
- Setup
- Characteristics

PROCEDURE

Set up and connections

In the first part of the exercise, you will set up the circuit and position the Background Suppression Photoelectric Switch.

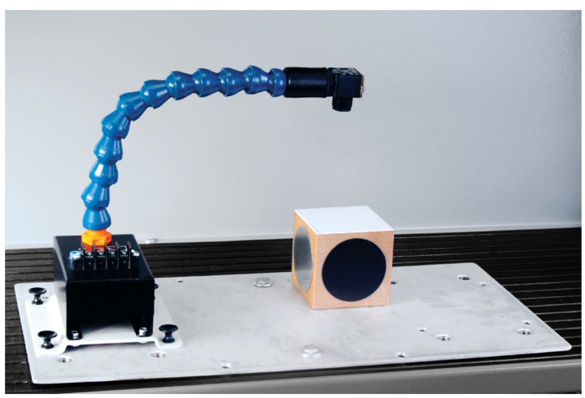
In the second part, you will observe the ability of the Background Suppression Photoelectric Switch to detect the presence of various objects over the surfaces of the Reflective Block.

Equipment required

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required to perform this exercise.

Setup

1. Set up the circuit shown in Figure 11.



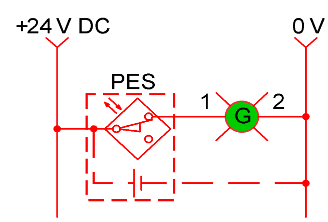


Figure 11. Circuit using the Background Suppression Photoelectric Switch.

2. Perform the Energizing procedure.

   Position the Reflective Block so the white plastic surface is parallel to the sensor sensing face at a distance of 100 mm (4 in). Raise the sensor slowly until the stability and output indicators turn off. Both indicators should be turned off without a target.

   In this part of the exercise, the Reflective Block surfaces are used as background surfaces.

Characteristics

3. Test the ability of the Background Suppression Photoelectric Switch to detect some objects moving over each surface of the Reflective Block at a distance of 12 mm (0.5 in). To do so, pass a finger over each surface and note in Table 3 if the sensor detects the presence of your finger.

Table 3. Surface detected by the Background Supression Photoelectric Switch.

Surface	Detected	Not detected
Black plastic surface		
White plastic surface		
Matte black metallic surface		
Shiny metallic surface (1)		
Depolarizing retroreflective surface		

(1) Depending on the angle that the light beam hits the shiny metallic surface, the sensor may detect its presence although the maximum sensing distance of the sensor is exceeded. If this is the case, modify the angle of the sensor slowly until it becomes deactivated.

4. Repeat your observations with other objects whose reflectivity differs (matte, shiny, bright, dark). What can you conclude from your observations?

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5. Compare the operation of the power indicator (green LED) to that of the output indicator (yellow LED). Note your observations.

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6. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you were introduced to the Background Suppression Photoelectric Switch.

You experimented on how it detects the presence of various objects moving over the surfaces of the Reflective Block.

Review Questions

1. What are background suppression photoelectric switches designed for?

2. How do the background suppression photoelectric switches ignore the background behind the target?

3. Name two advantages of background suppression photoelectric switches.

4. Explain how background suppression photoelectric switches can detect objects in front and behind the nominal sensing distance of the switch.

5. At which distance should the target be distanced from the background to obtain a reliable operation?

Polarized Retroreflective Photoelectric Switch

EXERCISE OBJECTIVE

- Introduce the Polarized Retroreflective Photoelectric Switch;
- Become familiar with its operation using the Reflective Block.

DISCUSSION

Retroreflective or retroflective sensing, is the most popular sensing mode. Retroreflective sensors can be used to detect most objects, including shiny objects. They contain both the emitter and receiver in the same housing. The light beam emitted by the light source is reflected by a special reflective surface and detected by the receiver, as shown in Figure 12. They are intended primarily for use in applications where an opaque target will completely block the light beam between the sensor and the reflective surface. Therefore, retroreflective sensors are not well suited to detect small and translucent objects.

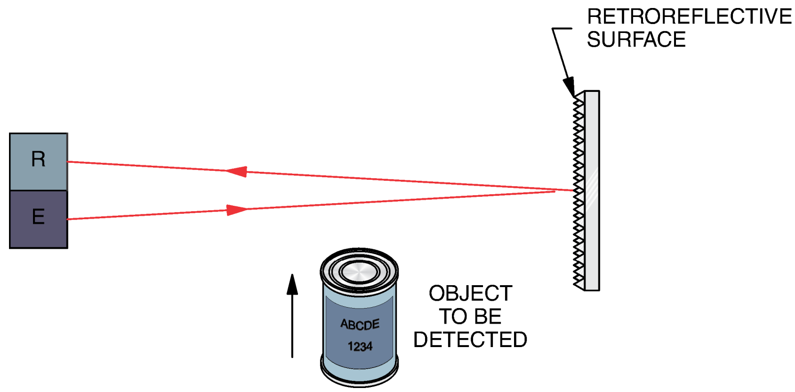


Figure 12. Retroreflective sensing.

Special reflectors or reflective tapes are used for retroreflective sensing. Unlike mirrors or other flat reflective surfaces, these reflective objects do not require perfect alignment. Misalignment of a reflector or reflective tape of up to 15° will typically not significantly reduce the operating margin of the sensing system. A wide selection of reflectors and reflective tapes is available. Some examples are shown in Figure 13.

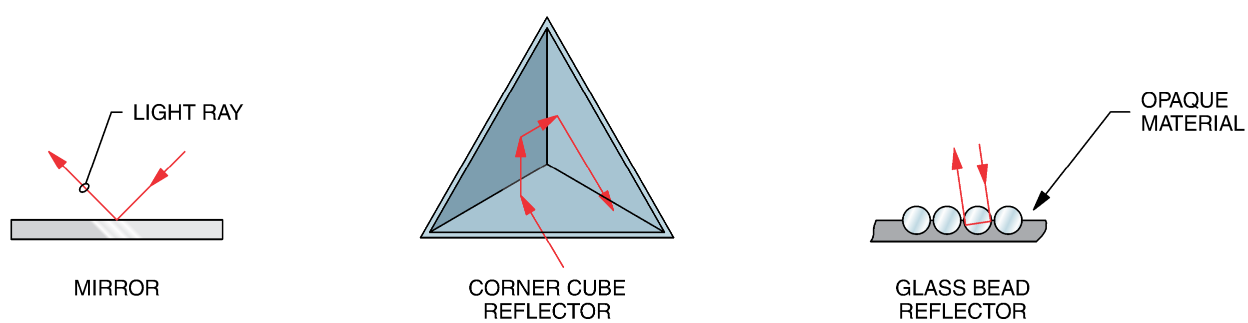


Figure 13. Retroreflective materials.

Occasionally, standard retroreflective sensors can be falsely triggered by reflections from shiny or highly reflective targets. To avoid this, polarized retroreflective sensing offers a better solution.

Polarized retroreflective sensors contain polarizing filters in front of the emitter and receiver. These filters are perpendicular, or 90° out of phase with each other, as shown in Figure 14. A depolarizing reflector is used to reflect the light.

In the absence of a target, the light emitted from the sensor is depolarized and reflected from the depolarizing reflector. Some of the reflected light passes through the polarizing filter in front of the receiver and is detected by the sensor, as shown in Figure 14 (a).

However, the light reflected by most targets is returned to the sensor with the same polarity, and cannot pass through the polarizing filter in front of the receiver, as shown in Figure 14 (b).

Polarized retroreflective sensors offer shorter sensing range than standard retroreflective sensors. Instead of infrared LEDs, they must use a less efficient visible red LED. They also have additional light losses caused by the polarizing filters.

Many standard reflectors depolarize light and are suitable for polarized retroreflective sensing. However, corner cube retroreflectors provide the highest signal return to the sensor. They have 2000 to 3000 times the reflectivity of white paper. For this reason, they are used to make safety reflectors for bicycles, cars, and signs.

As Figure 13 shows, corner cube reflectors consist of three adjoining sides arranged at right angles. When a light ray hits one of the adjoining sides, it is reflected to the second side, then to the third, and then back to its source in a direction parallel to its original course. You can experiment with the corner cube reflection by throwing a tennis ball into the corner of a room. The ball will return to you after bouncing off the three surfaces. Because of their high level of reflectivity, corner cube reflectors were placed on the moon by the Apollo astronauts and are still used today to measure the distance to the moon by timing laser light pulses reflected from Earth.

Polarized retroreflective sensors are often used to detect shiny objects. However, because the light may be depolarized as it passes through plastic film or stretch wrap, shiny objects may create detectable reflections (depolarized light) by the receiver if they are wrapped in clear plastic film.

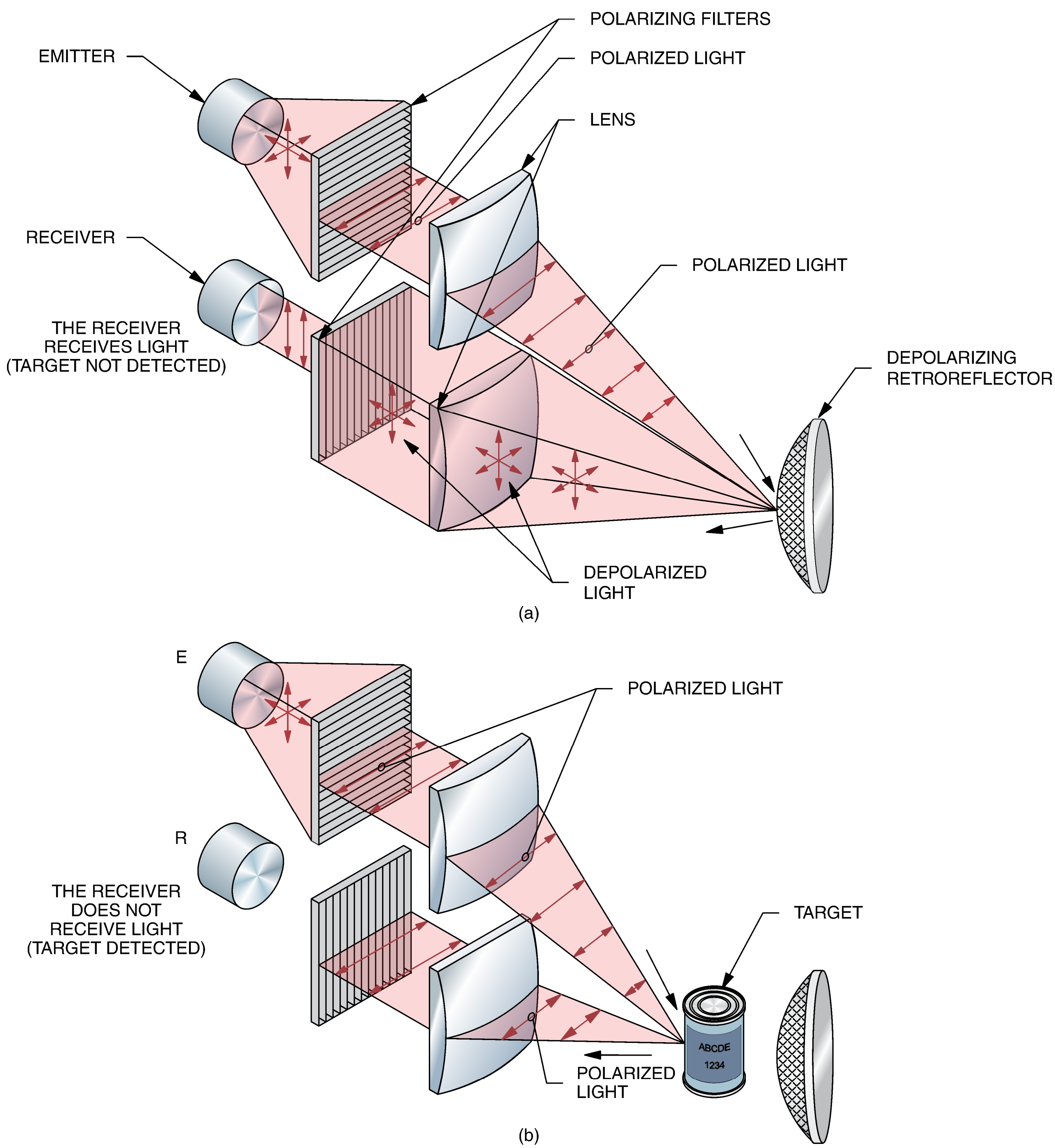


Figure 14. Polarized retroreflective sensing.

Most reflective tapes, like glass bead retroreflectors, do not depolarize light and are suitable only for use with standard retroreflective sensors.

The Polarized Retroflective Photoelectric Switch of your training system is shown in Figure 15. The sensor has a power indicator (green LED), an output indicator (yellow LED) that lights when the output is activated, and a stability indicator (orange LED) that lights when the excess gain exceeds 2.5. There is no sensitivity adjustment on this sensor. Other characteristics of the Polarized Retroflective Photoelectric Switch are shown in Table 4.

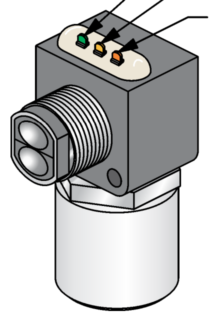


Figure 15. Polarized Retroflective Photoelectric Switch.

Table 4. Characteristics of the Polarized Retroflective Photoelectric Switch.

Characteristics of the polarized retroflective photoelectric switch		
Type		Polarized retroretlective
Transistor output type		Sourcing (PNP)
Sensing distance	Maximum	3 m (9.8 ft)
Light source	Type Wavelength	Visible red 660 nm (26.0 micro-inch)
Response time (sensor only)		1 ms
Light beam detection modes		Light operate/Dark operate (1)
Sensor output type		Relay output

(1) The sensor has light operate and dark operate outputs. The output relay coil is connected to the light operate output. The dark operate output is not used.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Set up and connections
- Equipment required
- Setup
- Characteristics
- Detection of various objects

PROCEDURE

Set up and connections

In the first part of the exercise, you will observe the ability of the Polarized Retroflective Photoelectric Switch to detect each surface of the Reflective Block.

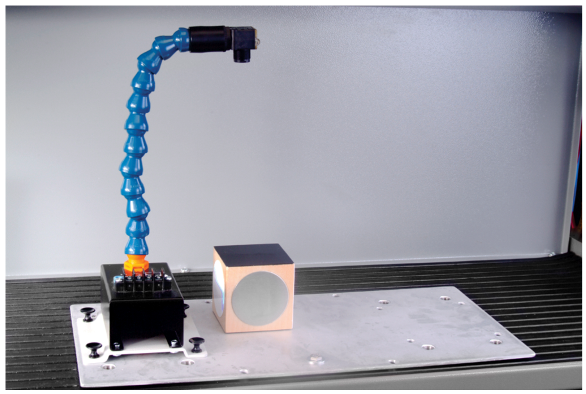
In the second part, you will observe the ability of the Polarized Retroflective Photoelectric Switch to detect the presence of opaque, transparent, and small objects.

Equipment required

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required to perform this exercise.

Setup

1. Set up the circuit shown in Figure 16.



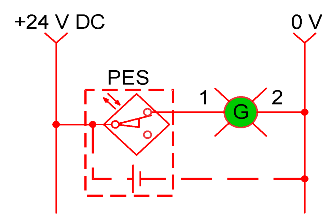


Figure 16. Circuit using the Polarized Retroflective Photoelectric Switch.

2. Perform the Energizing procedure.

3. Position the Reflective Block so the black plastic surface is parallel to the sensor sensing face at a distance of 200 mm (8 in), as shown in Figure 16.

Characteristics

4. Determine which surfaces are detected by the sensor. Note your observations in Table 5.

Table 5. Surfaces detected by the Polarized Retroreflective Photoelectric Switch.

Surface	Detected	Not detected
Black plastic surface		
White plastic surface		
Matte black metallic surface		
Shiny metallic surface		
Depolarizing retroreflective surface		

5. What can you conclude from your observations? Try with other distances between the sensor sensing face and the Reflective Block surfaces.

Detection of various objects

6. Position the Reflective Block so the depolarizing retroreflective surface is on top.

7. Is the green pilot light lit when an object is inserted between the sensing face and the depolarizing retroreflective surface? Explain why.

8. Pass a transparent object (plastic film) between the sensor and the Reflective Block. Does the photoelectric switch detect its presence? What does this mean?

9. Pass a small object like an electrical lead between the sensor and the Reflective Block. Does the photoelectric switch detect its presence? What does this mean?

10. Without modifying the sensor position, take the Reflective Block in your hand and hold the depolarizing retroreflective surface in front of the sensing face with an angle of approximately 45°. Does the photoelectric switch detect its presence in this position? What does this indicate?

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11. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

Conclusion

In this exercise, you were introduced to the Polarized Retroreflective Photoelectric Switch.

You observed how the Polarized Retroflective Photoelectric Switch detects the presence of various objects placed between the sensor and the depolarizing retroreflective surface of the Reflective Block. You saw that this sensor does not detect transparent objects. You also observed that it does not detect objects smaller than the light beam.

Review Questions

1. For which applications are the retroreflective photoelectric sensors designed?

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2. Name two reasons why polarized retroreflective sensors offer a shorter detection distance than standard retroreflective sensors.

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3. What are the purposes of the filters in a polarized retroreflective sensor?

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4. Name the type of retroreflector that provides the highest signal return.

5. Explain why retroreflective sensors are not well suited to detect small objects.

Capacitive Proximity Switch

EXERCISE OBJECTIVE

- Introduce the Capacitive Proximity Switch;
- Become familiar with its operation using the Reflective Block.

DISCUSSION

Capacitive proximity switches are designed to detect both metallic and nonmetallic objects. They detect their presence by generating an electrostatic field and detecting changes in this field caused by a target approaching. Capacitive proximity switches consist of a capacitive probe, oscillator, rectifier (detector circuit), and output circuit.

A capacitor is formed when two electrical conductors (plates), separated by an insulating material (dielectric), are connected to opposite poles of a voltage source, as shown in Figure 17. One plate becomes positively charged, while the second plate becomes negatively charged. The amount of electrical charge a capacitor can store is referred to as the capacitance.

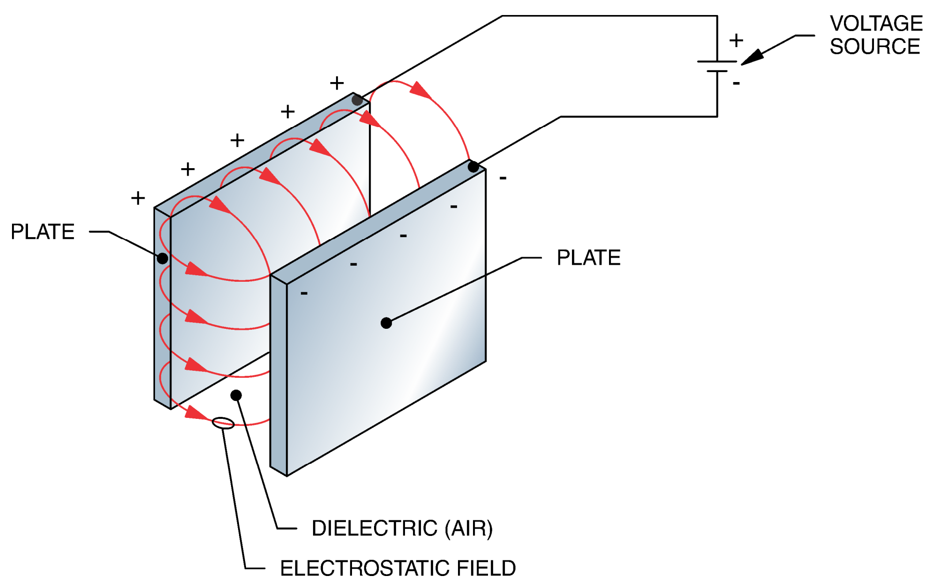


Figure 17. Charged capacitor.

Capacitive proximity switches operate on the same principle as a capacitor. The capacitive probe of the sensor acts as the positive pole, and the ground acts as the negative pole.

As Figure 18 shows, without a detectable object, the oscillator is inactive. As an object approaches the sensor, the dielectric constant (the ratio between the capacitance of a capacitor using an insulant and the capacitance that the same capacitor would have if it were used air as an insulant) of the capacitor changes. When the capacitance of the probe system reaches a specified threshold, the oscillator is activated.

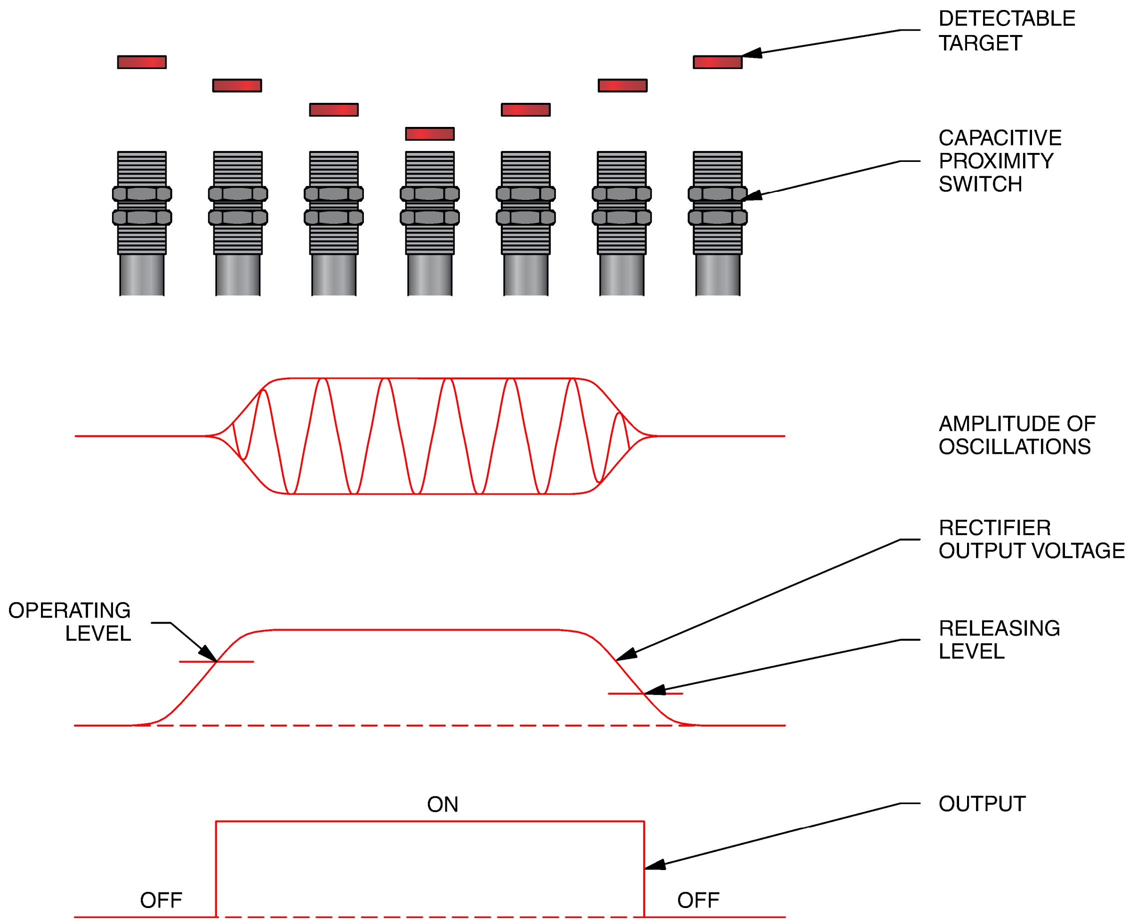


Figure 18. Operation of a capacitive proximity sensor.

The rectifier converts the AC oscillations to a DC voltage. When the DC voltage reaches the "operating level," the sensor switches the state of the output transistor to the activated mode. When the DC voltage decreases to the "releasing level," the sensor switches the state of the output transistor to the deactivated mode.

Because the sensor is activated by a change in electrical energy rather than magnetic energy, it detects both metallic and nonmetallic materials.

The sensing distance of capacitive proximity switches depends on the size of both the probe and the target object. Large probes have a higher capacitance than small ones, so an object will influence the electrostatic field of a large probe from a greater distance. These distances are standardized against a mild steel target, 1 mm (0.039 in) thick, with side lengths equal to the diameter of the active face or three times the nominal switching distance, whichever is greater. Objects smaller than the standard target will lessen the sensing distance, and objects larger will not affect the sensing distance.

The dielectric constant of the target material also affects the sensing distance. For example, a capacitive proximity switch will detect glass at only 40% of the standard distance, and paper at 10%. Materials having a low dielectric constant are difficult to detect. Temperature and humidity may also affect the sensing distance. For best results, capacitive proximity switches should be used in an environment with constant temperature and humidity. Even when used in perfect conditions, capacitive proximity switches should not be located at more than 80% of the maximum sensing distance for that particular target material.

Because nearby objects may affect the operation of capacitive proximity switches, they must be spaced from surrounding conductive objects and/or other sensors. Refer to the manufacturer instructions to obtain the distance requirements.

Capacitive proximity sensors can be shielded or unshielded. Shielded sensors are constructed with a metallic band surrounding the capacitive probe. This helps to direct the electrostatic field to the front of the sensor and results in a more concentrated field. Shielded sensors are best suited for sensing low dielectric (difficult to sense) materials due to their highly concentrated electrostatic fields.

Most capacitive proximity switches are equipped with a sensitivity adjustment screw. Because they measure a dielectric gap, it is important to compensate for target and application conditions. The sensitivity of capacitive proximity switches can be adjusted so they will be activated by the presence of a full container, but not by the presence of an empty container. They are ideally suited for liquid level control, as shown in Figure 19.

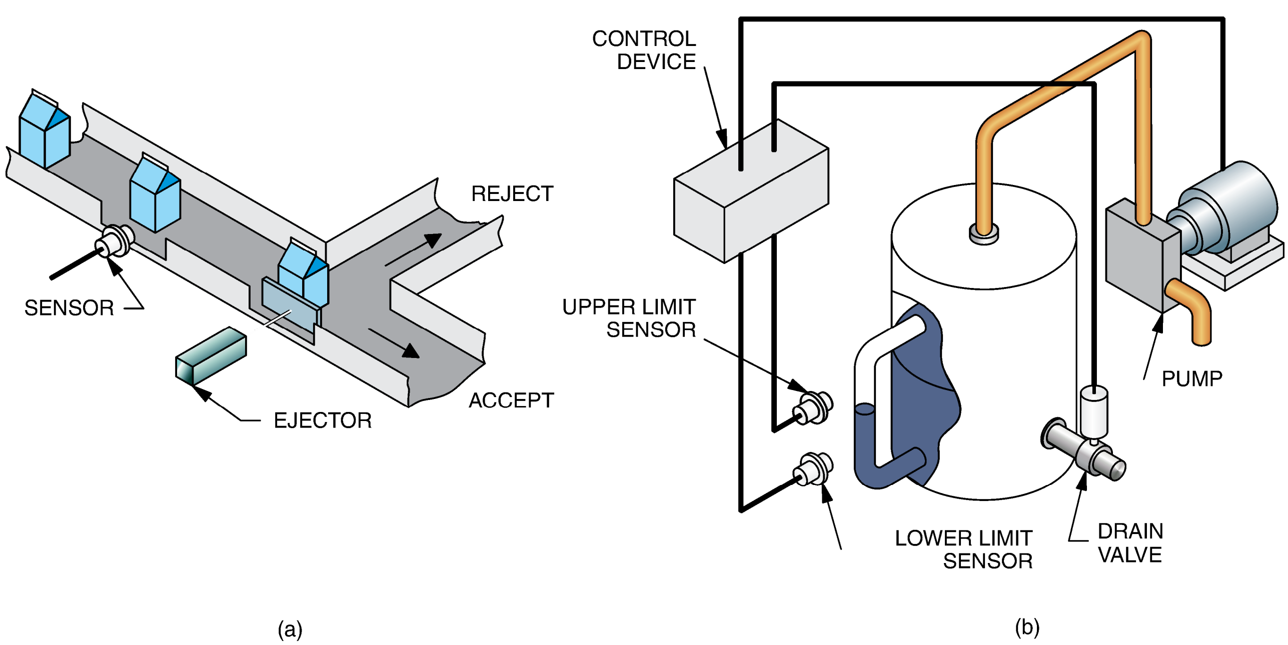


Figure 19. Sensing liquid level using capacitive proximity switches.

Figure 19 (a) shows a capacitive proximity switch detecting the fill level of milk cartons. Cartons that are not filled at the proper level are rejected. Figure 19 (b) shows two capacitive proximity switches maintaining a particular fill level. If the fluid level in the tank gets too high, the top switch will signal the controller to lower the fluid level. If the fluid level gets too low, the bottom switch will signal the controller to raise the fluid level.

The Capacitive Proximity Switch of your training system is shown in Figure 20.

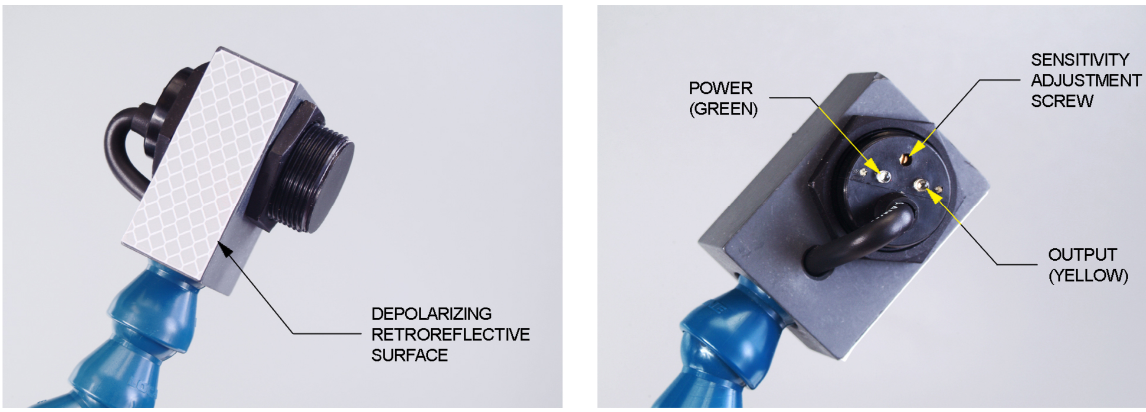


Figure 20. Capacitive Proximity Switch.

As Figure 20 shows, the sensor has a sensitivity adjustment screw, a power indicator, and an output indicator that lights when the output is activated. Other characteristics of the Capacitive Proximity Switch are shown in Table 6.

Table 6. Characteristics of the Capacitive Proximity Switch.

Characteristics of the capacitive proximity switch	
Type	Capacitive unshielded
Transistor output type	Sourcing (PNP)
Sensing distance	5 to 20 mm (0.2 to 0.8 in) adjustable
Switching frequency (Hz)	100

Procedure Outline

The Procedure is divided into the following sections:

- Set up and connections
- Equipment required
- Setup
- Sensitivity adjustment
- Characteristics
- Liquid detection

PROCEDURE

Set up and connections

In the first part of the exercise, you will adjust the sensitivity of the Capacitive Proximity Switch to detect the presence of the shiny metallic surface of the Reflective Block.

In the second part, you will observe the ability of the Capacitive Proximity Switch to detect the presence of various objects.

In the third part, you will observe that the Capacitive Proximity Switch can detect the presence of liquid in a plastic container.

Equipment required

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required to perform this exercise.

Setup

1. Set up the circuit shown in Figure 21.

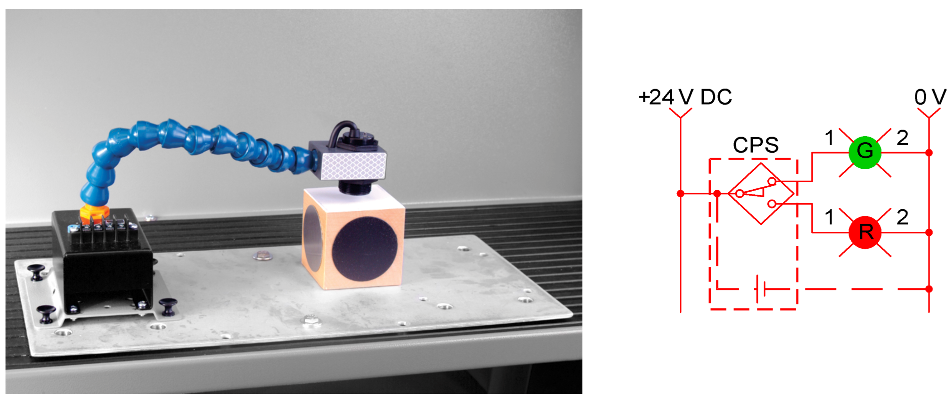


Figure 21. Circuit using the Capacitive Proximity Switch.

2. Position the Reflective Block so the white plastic surface is placed at a distance of 10 mm (0.4 in) from the sensor sensing face, as shown in Figure 21.

Sensitivity adjustment

3. Perform the Energizing procedure.

A capacitive sensor should not be hand-held during setup. Because your hand has a dielectric constant greater than air, the sensor may detect your hand rather than the intended target.

4. Adjust the sensitivity of the Capacitive Proximity Switch as follows:

- Place the Reflective Block away from the front (i.e., away from the detection area) of the sensor for this part of the setting.
- Using a screwdriver, carefully turn the sensitivity adjustment screw clockwise until the output indicator turns on.

If the output indicator is already lit when the power is turned on, turn the adjustment screw in the counterclockwise direction until the output indicator turns off. Then, turn the sensitivity adjustment screw clockwise until the output indicator turns on.

- Replace the Reflective Block as previously.
- Carefully turn the sensitivity adjustment screw counterclockwise until the sensor turns off and the output indicator goes out. Note the number of revolutions between the "on" and "off" positions.
- If the number of revolutions is greater than one and a half, the sensor will provide stable output. If the number is less than one and a half, increase or decrease the distance between the target surface and the sensor as necessary to allow at least one and a half revolutions between the "on" and "off" positions.
- Turn the sensitivity adjustment screw clockwise to the midpoint between the "on" and "off" points.

Characteristics

5. Determine which surfaces are detected by the sensor. Note your observations in Table 7.

Table 7. Surfaces detected by the Capacitive Proximity Switch.

Surface	Detected	Not detected
Black plastic surface		
White plastic surface		
Matte black metallic surface		
Shiny metallic surface		
Depolarizing retroreflective surface		

6. Does the Capacitive Proximity Switch detect all surfaces of the Reflective Block, whatever the surfaces covering the plastic block?

❑ Yes ❑ No

7. Place the Reflective Block away from the front (i.e., away from the detection area) of the proximity switch.

Pass your hand near the proximity switch without touching the sensing face. Does the proximity switch detect the presence of your hand, confirming that the sensor should not be hand-held during sensitivity adjustment?

❑ Yes ❑ No

8. Place some objects of different materials like a sheet of paper, plastic cardboard, glass, and others in front of the sensor sensing face. Note which materials are detected and which ones are not detected in Table 8.

Table 8. Materials detected by the Capacitive Proximity Switch.

Material	Detected	Not detected

The dielectric constant of certain materials, like paper, plastic, polystyrene, cardboard, and glass, is very low. These materials are difficult to detect by means of capacitive proximity switches. A table of dielectric constants of common materials is included in the manufacturer literature supplied with the training system on a CD.

9. Turn off the Lockout Module.

Liquid detection

10. Fill the pot with water to mid-height and position it as shown in Figure 22.

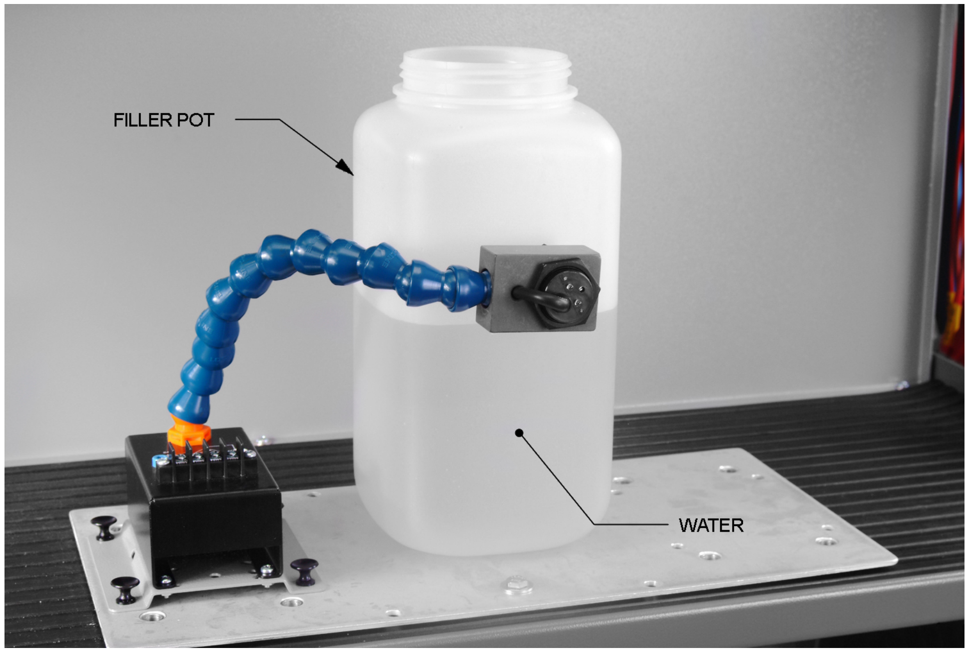


Figure 22. Liquid detection using the Capacitive Proximity Switch.

11. Place the sensing face of the Capacitive Proximity Switch against the filler pot, as shown in Figure 22. Make sure that the bottom of the sensing face is at least 6 mm (1/4 in) above the water level.

12. Turn on the Lockout Module.

Turn the adjustment screw in the counterclockwise direction until the output indicator turns off. Turn it one more turn in the counterclockwise direction.

If the output indicator is already turned off when the poweris turned on, turn it on first by turning the adjustment screw in the clockwise direction.

Position the sensing face of the Capacitive Proximity Switch against the filler pot at 6 mm (1/4 in) below the water level.

Does the Capacitive Proximity Switch change status when the sensing face goes from an empty section to a filled section? Repeat your observations.

❑ Yes ❑ No

13. Do your observations confirm that the Capacitive Proximity Switch can detect the presence of water in a container?

❑ Yes ❑ No

14. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, empty the filler pot, and return the equipment to the storage location.

CONCLUSION

In this exercise, you were introduced to the Capacitive Proximity Switch.

You experimented with how to adjust the sensitivity of the Capacitive Proximity Switch to detect a particular material. You observed the ability of the sensor to detect the presence of various objects. You observed that it is not affected by surface reflectivity, but by the dielectric constant of the material.

In the last part of the exercise, you observed that the Capacitive Proximity Switch can detect the presence of liquid in a plastic container.

REVIEW QUESTIONS

1. What types of material do capacitive proximity switches detect?

___

___

___

2. What are the four main sections of a capacitive proximity switch?

___

___

___

3. Name two parameters that affect the sensing distance of a capacitive proximity switch.

___

___

___

4. Explain why capacitive proximity switches must be spaced from surrounding surfaces and/or other sensors.

___

___

___

5. Explain why most capacitive proximity switches are equipped with a sensitivity adjustment.

___

___

___

Inductive Proximity Switch

EXERCISE OBJECTIVE

- Introduce the Inductive Proximity Switch;
- Become familiar with its operation using the Reflective Block.

DISCUSSION

Inductive proximity switches are designed to detect the presence of metallic objects. They detect their presence by generating an electromagnetic field and detecting changes in this field caused by an approaching metallic object. Inductive proximity switches consist of a coil, oscillator, rectifier (detector circuit), and output circuit, as shown in Figure 23.

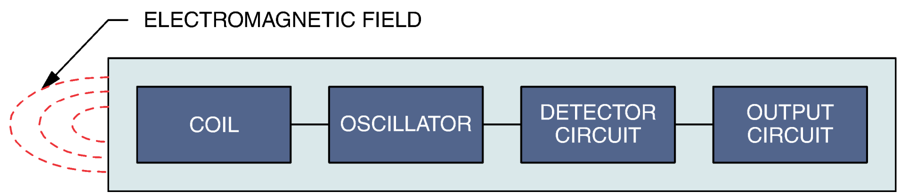


Figure 23. Inductive proximity sensor.

The oscillator produces a high frequency voltage applied to the coil to produce an electromagnetic field. As Figure 24 shows, when a metallic object enters the magnetic field, eddy currents are induced in the object. This causes a loss in energy and a reduction in the magnitude of the oscillations. When the energy loss becomes important enough, the oscillator stops functioning.

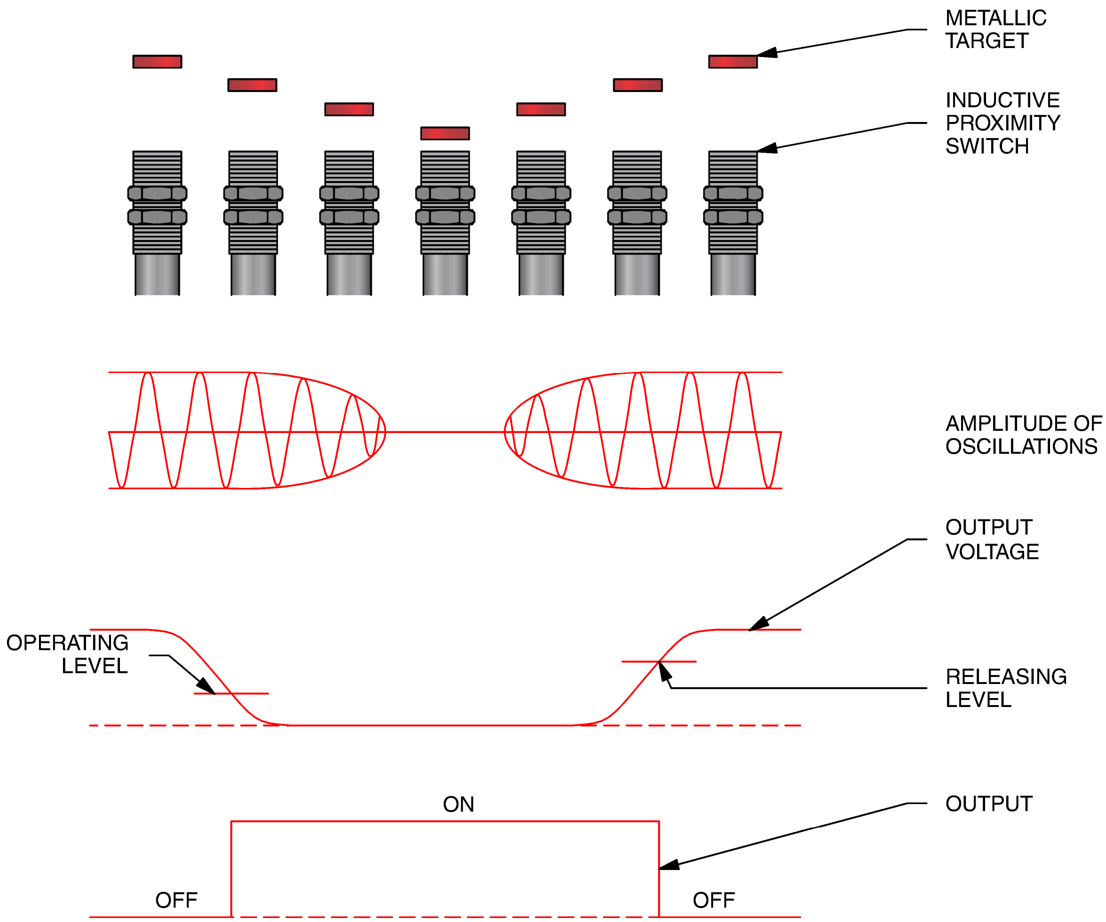


Figure 24. Operation of an inductive proximity switch.

The rectifier converts the AC output signal from the oscillator to a DC voltage. When the DC voltage drops below the "operating level," the sensor switches the output transistor to the activated mode. When the DC voltage raises to the "releasing level," the sensor switches the output transistor to the deactivated mode.

Because the magnetic field associated with the induced eddy currents is quite small, the maximum sensing distance of an inductive proximity switch is also quite small. Typical sensing distances are from 1 to 15 mm (0.04 to 0.6 in).

These distances are standardized against a mild steel target, 1 mm (0.04 in) thick, with side lengths equal to the diameter of the active face or three times the nominal switching distance, whichever is greater. Objects smaller than the standard target will lessen the maximum sensing distance, and objects larger than the standard target may increase the sensing distance.

Sensing distance for capacitive proximity sensors depends on the size of the probe and the target. With inductive proximity sensors, the sensing distance depends on the size of the coil and the composition of the target object. The chart in Table 9 shows the effect of target composition on the sensing distance.

Table 9. Sensing distance

Type of metal	Correction factor
Mild steel	1.0
Stainless Steel	0.7 – 0.8
Brass	0.4 – 0.5
Aluminum	0.3 – 0.4
Copper	0.2 – 0.3

For example, an inductive proximity switch detects copper at approximately 25% of the standard sensing distance, and stainless steel at approximately 75%. Nonmetallic objects are very poor conductors and will not be detected at all.

Because nearby metallic objects affect the operation of inductive proximity switches, they must be spaced from surrounding metallic objects and/or other sensors, as shown in Figure 25. The distances shown in Figure 25 apply to the Inductive Proximity Switch of your training system.

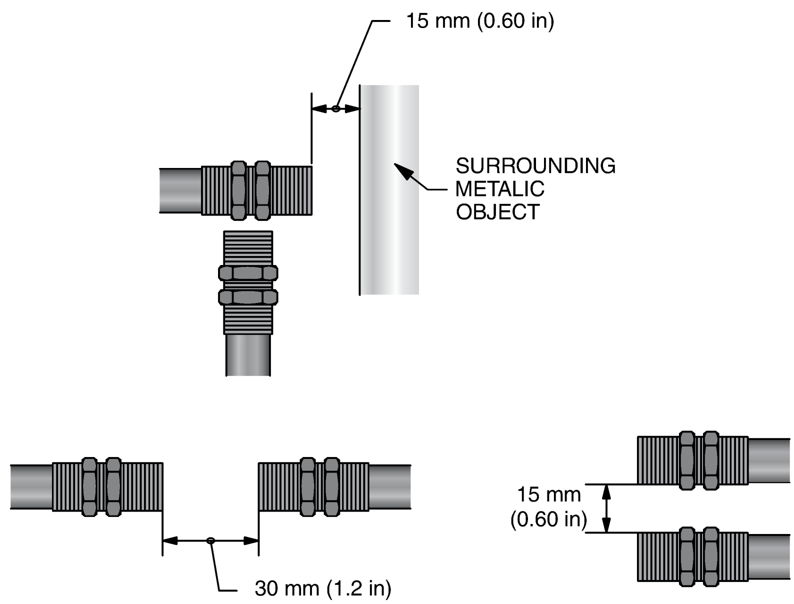
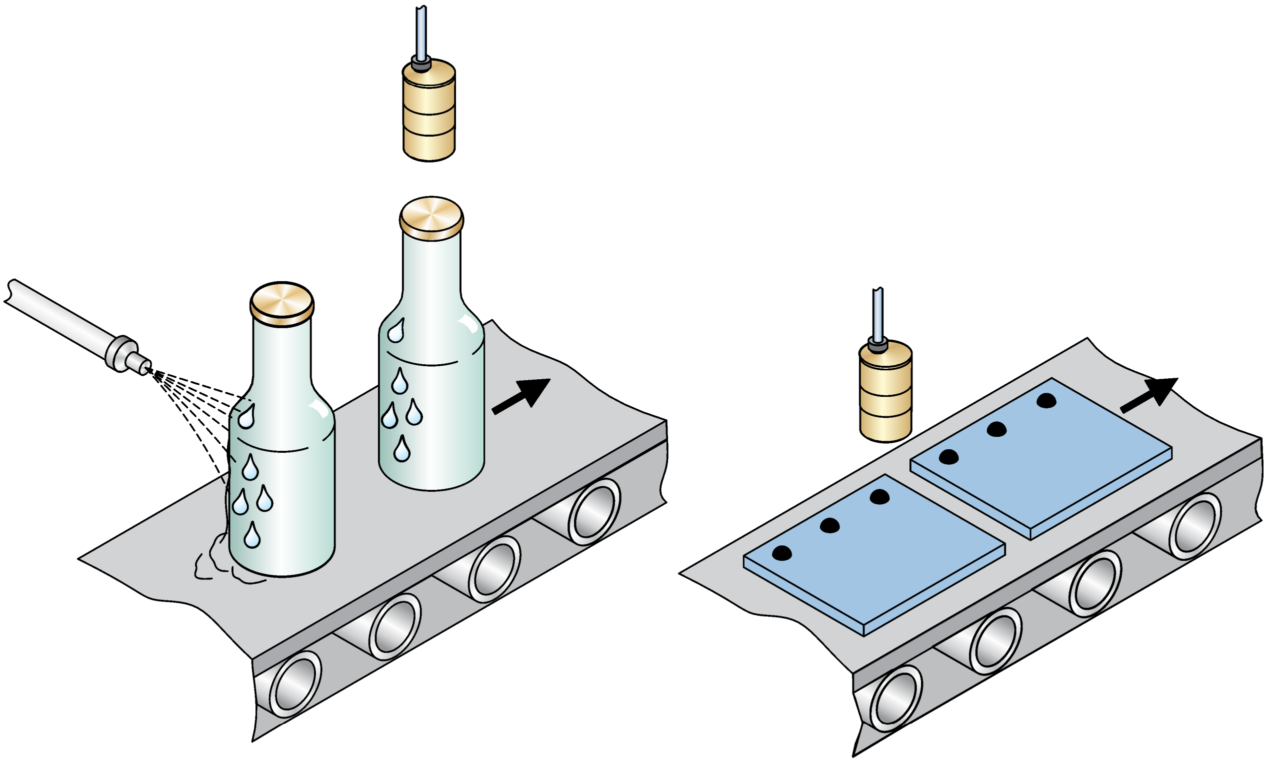


Figure 25. Minimum mounting distances.

Inductive proximity sensors can be shielded or unshielded. Shielded sensors are constructed with a metallic band surrounding the coil. This helps to direct the electromagnetic field to the front of the sensor and results in a more concentrated field.

Figure 26 (a) shows an inductive proximity switch checking bottles for bottle caps. Bottles without caps are rejected. Inductive proximity switches work better than other proximity switches in this application because they are not affected by high humidity. In Figure 26 (b) an inductive proximity switch counts the rivets on a finished work piece.



(a) (b)

Figure 26. Inductive proximity switch applications.

The Inductive Proximity Switch of your training system is shown in Figure 27. The sensor has an output indicator (red LED) that lights when the output is activated, and there is no sensitivity adjustment. Other characteristics of the Inductive Proximity Switch are shown in Table 10.

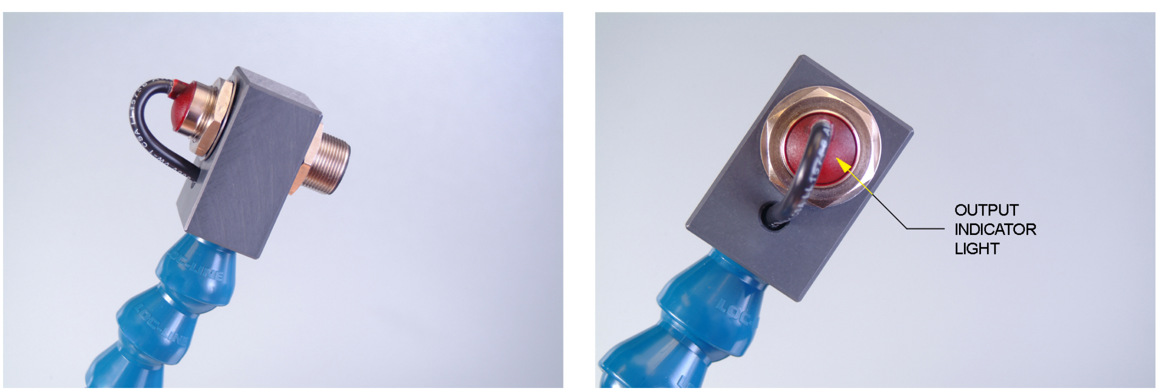


Figure 27. Inductive Proximity Switch.

Table 10. Characteristics of the Inductive Proximity Switch.

Characteristics of the Inductive Proximity Switch	
Type	Inductive shielded
Transistor output type	Sourcing (PNP)
Maximum sensing distance	5 mm (0.2 in)
Switching frequency (Hz)	1000

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Set up and connections
- Equipment required
- Setup
- Characteristics
- Sensing distance

PROCEDURE

Set up and connections

In the first part of the exercise, you will observe the ability of the Inductive Proximity Switch to detect the presence of various objects.

In the second part, you will determine the maximum sensing distance of the Inductive Proximity Switch by using the Reflective Block.

Equipment required

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required to perform this exercise.

Setup

1. Set up the circuit shown in Figure 28.

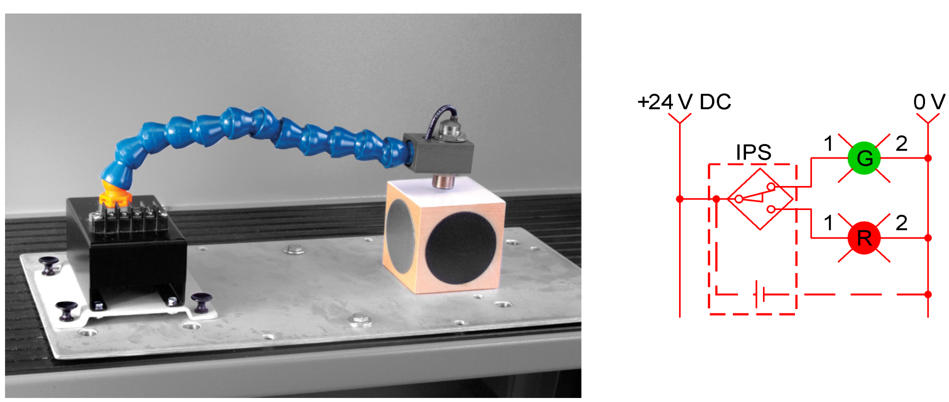


Figure 28. Circuit using the Inductive Proximity Switch.

2. Position the Reflective Block at a distance of 3 mm (0.125 in) from the sensor sensing face, as shown in Figure 28.

Characteristics

3. Perform the Energizing procedure.

4. Determine which surfaces are detected by the sensor. Note your observations in Table 11.

Table 11. Surfaces detected by the Inductive Proximity Switch.

Surface	Detected	Not detected
Black plastic surface		
White plastic surface		
Matte black metallic surface		
Shiny metallic surface		
Depolarizing retroreflective surface		

5. Does the Inductive Proximity Switch detect all surfaces of the Reflective Block, whatever the surfaces covering the plastic block?

   ❑ Yes ❑ No

6. Place some objects of different materials (metallic and nonmetallic) against the sensor. Do your observations confirm that only metallic surfaces are detected by the Inductive Proximity Switch?

   ❑ Yes ❑ No

Sensing distance

7. Determine the maximum sensing distance of the Inductive Proximity Switch. To do so, place the shiny metallic surface of the Reflective Block against the sensor. Raise the sensor slowly away from the metallic surface until the red pilot light turns off. Determine the distance.

   Maximum sensing distance = ____________

8. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you were introduced to the Inductive Proximity Switch.

You observed the ability of the Inductive Proximity Switch to detect the presence of various objects.

In the last part of the exercise, you observed that the maximum sensing distance of this type of sensor is quite short.

REVIEW QUESTIONS

1. What type of material do inductive proximity switches detect?

2. What are the four main parts of an inductive proximity switch?

3. What causes the maximum sensing distance of an inductive proximity switch to be relatively short?

4. Explain why inductive proximity switches must be spaced from surrounding metallic surfaces and/or other sensors.

5. Name two parameters that affect the sensing distance of an inductive proximity switch.

Limit Switch

EXERCISE OBJECTIVE

- Introduce the Limit Switch;
- Learn how and when limit switches are used.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Actuators

DISCUSSION

A limit switch is an electro-mechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection. Limit switches are used in a variety of applications and environments because of their ruggedness, simple visible operation, ease of installation, and reliability of operation.

In an automobile, for example, limit switches are used to automatically turn on the lights when a door is opened.

Limit switch contacts may be NO, NC, or any combination of NO and NC contacts. To prevent arcing or welding of the contacts, they must be connected to the proper polarity. There is no arcing between the contacts when the contacts energize and de-energize the load as long as the contacts are of the same polarity. Arcing or welding may occur if the contacts are connected to opposite polarity, as shown in Figure 29.

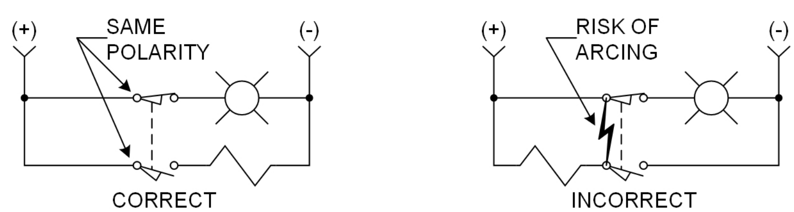


Figure 29. Arcing or welding of the contacts may occur if the contacts are connected to opposite polarity.

Contacts must be selected according to the voltage and current of the load and manufacturer specifications. A relay or a contactor must be used to interface the limit switch with the load if the load current exceeds the contact rating.

Actuators

There are two types of limit switches: rotary lever-actuated and plunger-actuated.

The rotary lever-actuated limit switch works on the following principle: an object hits the end of a lever arm, which rotates a shaft that operates the switch contacts. In some rotary lever-actuated limit switches, the actuator attached to the shaft can be interchanged.

A plunger-activated limit switch works on the following principle: an object hits the end of the plunger, which is pressed in to operate the contacts of the switch.

The Limit Switch module of your training system is shown in Figure 30. It includes a set of NC and NO contacts. The position of the actuator is adjustable using a rod and a knob. The length of the lever arm is also adjustable. Other characteristics of the Limit Switch are shown in Table 12.

Figure 30. Limit Switch module.

Table 12. Characteristics of the Limit Switch.

Characteristics of the Limit Switch				
Contacts	NO and NC, snap acting			
AC rating	600 V	500 V	250 V	120 V
	1.2 A	1.4 A	3 A	6 A
DC rating	600 V	500 V	250 V	125V
	0.4 A	0.55 A	1.1 A	2.2 A
Actuator type	adjustable lever			
Max Switching Frequency	6000 operations per hour			

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Set up and connections
- Equipment required
- Characteristics

PROCEDURE

Set up and connections

In this exercise, you will experiment with the operation of the Limit Switch module.

Equipment required

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required to perform this exercise.

Characteristics

1. What types of contacts are available on the Limit Switch module?

____

____

2. What is the type of the Limit Switch?

____

____

3. Referring to the ladder diagram shown in Figure 31, indicate which pilot light turns off when the Limit Switch is activated.

____

4. Set up the circuit shown in Figure 31.

Figure 31. Circuit using the Limit Switch.

5. Perform the Energizing procedure.

6. Press on the roller to activate the Limit Switch. Describe what happens.

____

____

7. Is your prediction confirmed?

❑ Yes ❑ No

8. Pull up the lever of the Limit Switch. Do your observations confirm that the switch operates in both directions?

❑ Yes ❑ No

9. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you were introduced to the Limit Switch.

You observed that the Limit Switch operates in both directions.

REVIEW QUESTIONS

1. What precaution must be taken to prevent arcing or welding of the contacts of a limit switch?

____

____

____

2. Name the two types of limit switches.

3. What should be done if the load current exceeds the contact rating of the limit switch?

4. What is the main difference between a limit switch and a photoelectric switch?

5. On which principle does the rotary lever-actuated limit switch work?

Motor-Operated Circuits Using Sensors (optional)

EXERCISE OBJECTIVE

- Introduce the Reversible AC Motor;
- Determine the ability of the sensors of the training system to detect the presence of holes in three disks having different characteristics.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Reversible AC Motor characteristics
- Motor installation
- Disks
- Installation of a sensor on the Reversible AC Motor casing
  Installation of the limit switch on the reversible ac motor.

DISCUSSION

Reversible AC Motor characteristics

The Reversible AC Motor, model 3174-3, is a permanent split capacitor motor. The rotation direction is reversible and the output speed is 30 r/min. Other characteristics of the Reversible AC Motor, are shown in Table 13.

Table 13. Reversible AC Motor characteristics.

Parameter	Rating
Voltage	115 V, 60/50 Hz
Power rating (hp)	1/100
Full-load current (A)	0.28
Motor type	permanent split capacitor
Rotation	reversible
Enclosure type	open
Thermal protection	none
Gear ratio	99:1
Rotation speed (r/min)	30
Full load torque	0.84 n·m (7.5 lb·in)
Note: The ratings are based on 60 Hz operation.	

Motor installation

The Reversible AC Motor can be secured to the work surface by means of push-lock fasteners, or using the quick-lock knobs. Throughout this exercise, the motor is shown with push-lock fasteners.

Position the Reversible AC Motor on the work surface, as shown in Figure 32. (If you are using the system in a 8001 or 8006 EMS environment, place the motor on a standard table.) Align the push-lock fasteners with the perforations, then push on the fasteners.

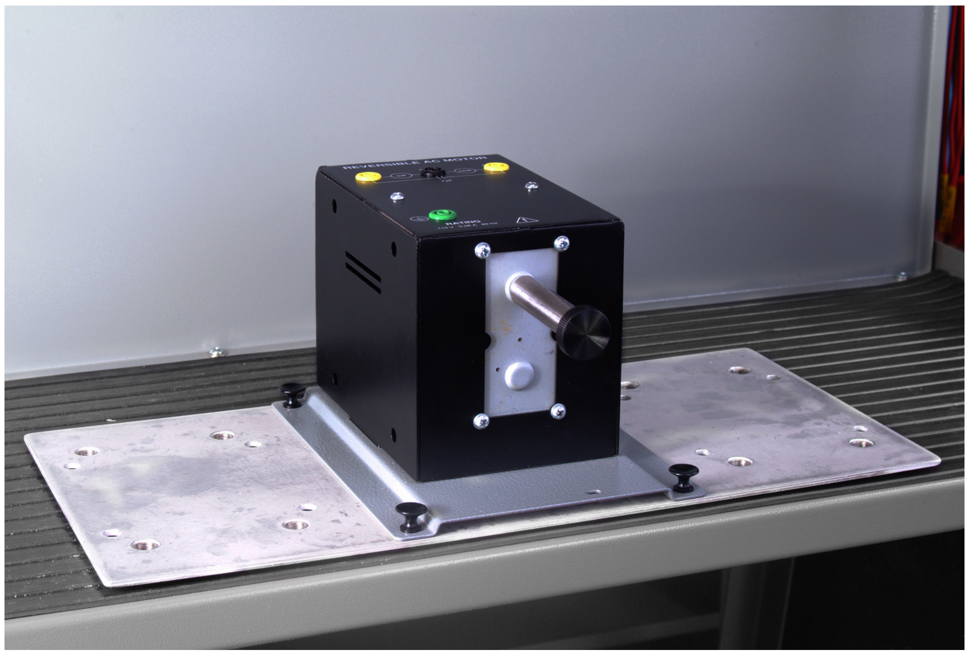


Figure 32. Installation of the Reversible AC Motor.

Disks

Three disks, provided with holes, and having different characteristics, are supplied with the Reversible AC Motor: a metallic disk, a transparent plastic disk, and a fiber disk.

To install a disk, install the bushing (supplied with the motor) on the motor shaft, and tighten the set screw. Be sure to tighten the set screw on the flat surface of the motor shaft.

Align the opening in the center of the disk to fit the end of the bushing, as shown in Figure 33. Fix the disk in place by tightening the knob. The knob must be provided with a rubber washer and a metallic flat washer. The rubber washer must be placed on the disk side.

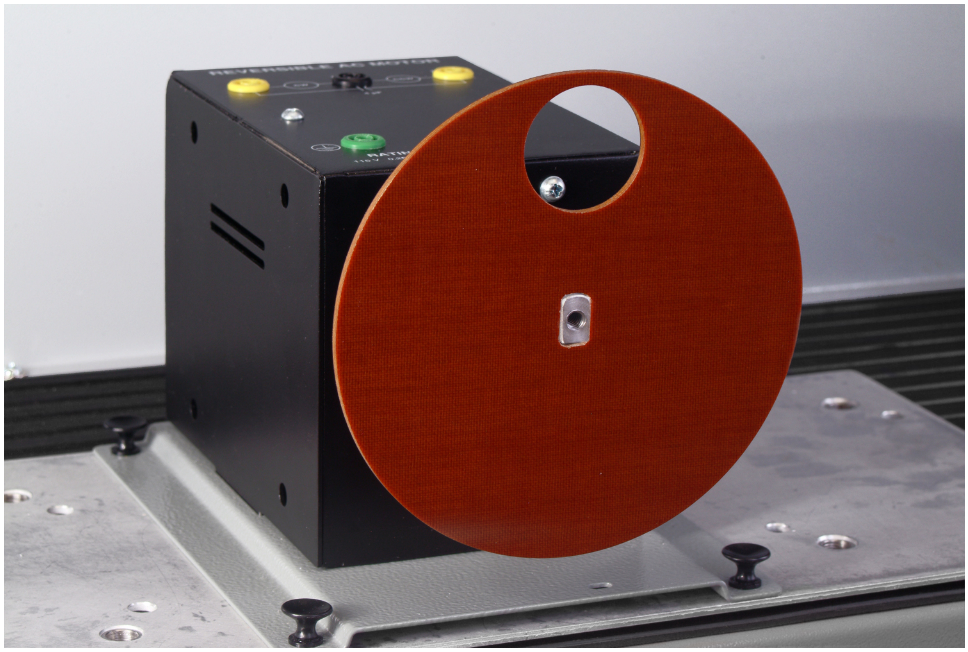


Figure 33. Align the opening in the center of the disk to fit the end of the bushing.

Installation of a sensor on the Reversible AC Motor casing

Position the sensor on the Reversible AC Motor casing, as shown in Figure 34. Align the push-lock fasteners with the perforations, then push on the fasteners.

Position the sensing face as required.

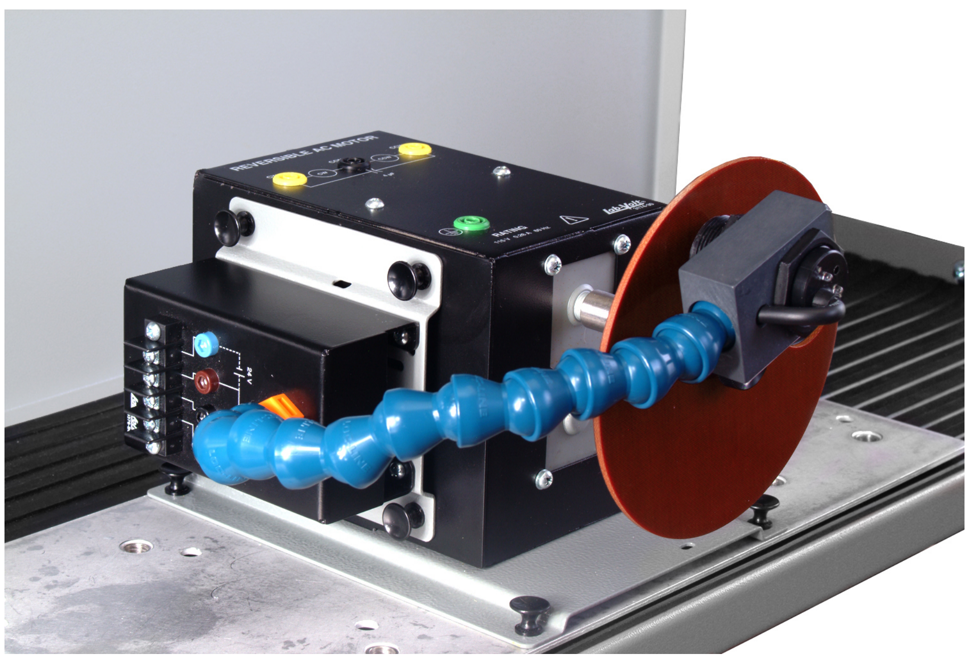


Figure 34. Installation of a sensor on the Reversible AC Motor casing.

Installation of the limit switch on the reversible ac motor

Install the Limit Switch on the Reversible AC Motor casing.

Install and position the metallic disk off-center, as shown in Figure 35.

Position the Limit Switch so the roller at the extremity of the lever is slightly in contact with the edge of the metallic disk when facing the slot. As Figure 35 shows, the lever must not be bent in this position. Fix the Limit Switch by tightening the knob.

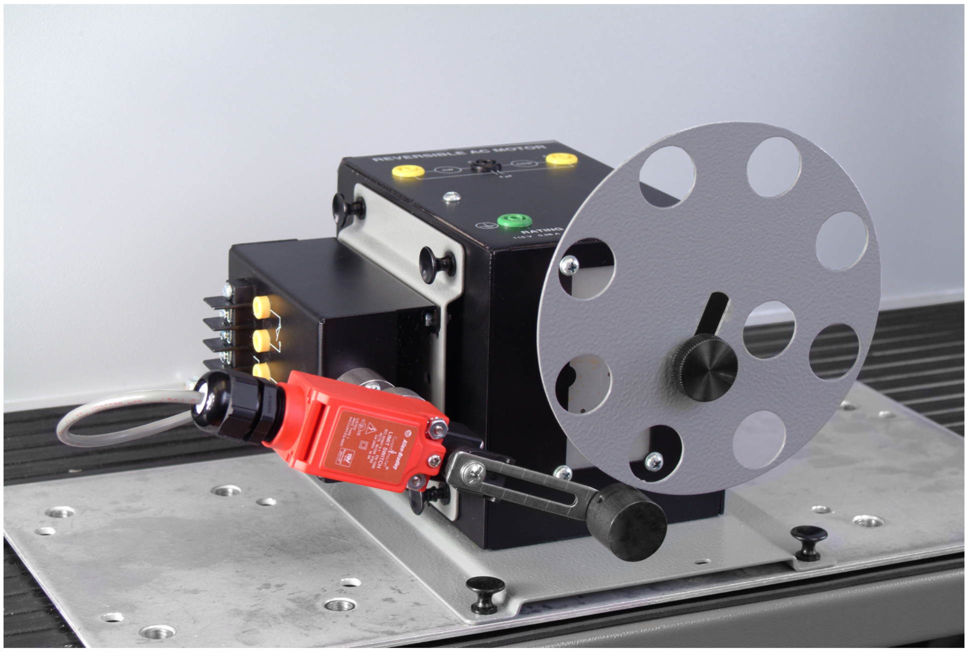


Figure 35. Install and position the metallic disk off-center.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Set up and connections
- Equipment required
- Characteristics

PROCEDURE

Set up and connections

In this exercise, you will check the ability of the sensors of your training system to detect the presence of holes in three disks having different characteristics. The disks will be mounted to the Reversible AC Motor shaft.

Equipment required

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required to perform this exercise.

Characteristics

1. Referring to what has been seen in the previous exercises, identify the disks for which the sensors will detect the presence of holes in the position shown in Figure 36. Enter your answers in Table 14.

Table 14. Disk holes detected by the sensors.

Sensor type	Disk type		
	Metallic	Transparent plastic	Fiber
Background Suppression Photoelectric Switch			
Polarized Retroreflective Photoelectric Switch			
Capacitive Proximity Switch			
Inductive Proximity Switch			

2. Set up the circuit shown in Figure 36.

3. Install the metallic disk (centered).

4. Perform the Energizing procedure.

   Validate your predictions for each sensor.

   Do your observations confirm your predictions?

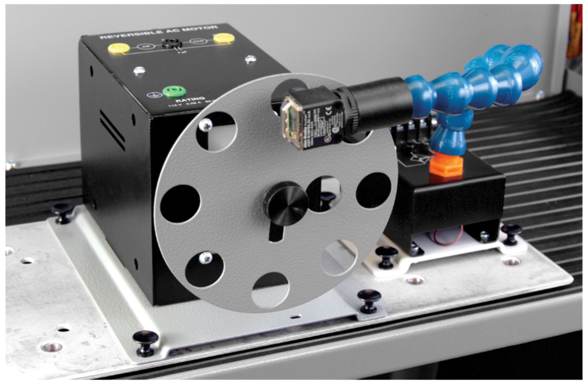
   ❑ Yes ❑ No

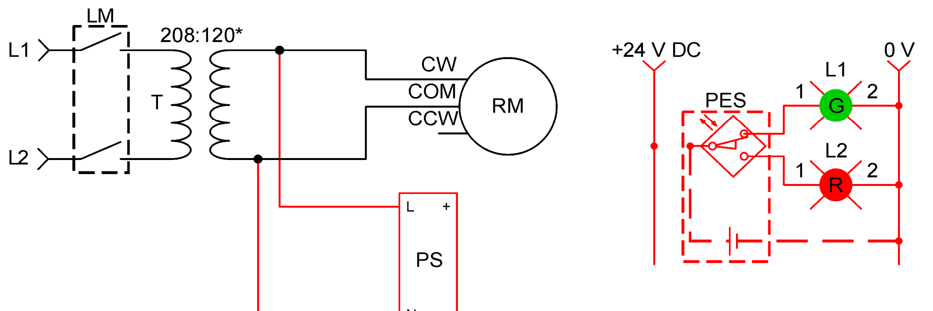
5. Turn off the Lockout Module.

6. Repeat your observations with the transparent plastic, and fiber disks.

   Do your observations confirm your predictions?

   ❑ Yes ❑ No





*208:120 FOR 120 V - 60 Hz NETWORK
380:110 FOR 220 V - 50 Hz NETWORK
415:110 FOR 240 V - 50 Hz NETWORK
380:120 FOR 220 V - 60 Hz NETWORK

LEGEND

L1	=	PILOT LIGHT (GREEN)
L2	=	PILOT LIGHT (RED)
LM	=	LOCKOUT MODULE
PES	=	PHOTOELECTRIC SWITCH
PS	=	DC POWER SUPPLY
RM	=	REVERSIBLE MOTOR (SINGLE PHASE)
T	=	CONTROL VOLTAGE TRANSFORMER

Figure 36. Circuit used to detect the presence of hole(s) in the disks.

7. What should be done for the Polarized Retroreflective Photoelectric Switch to detect the holes in the disks?

____

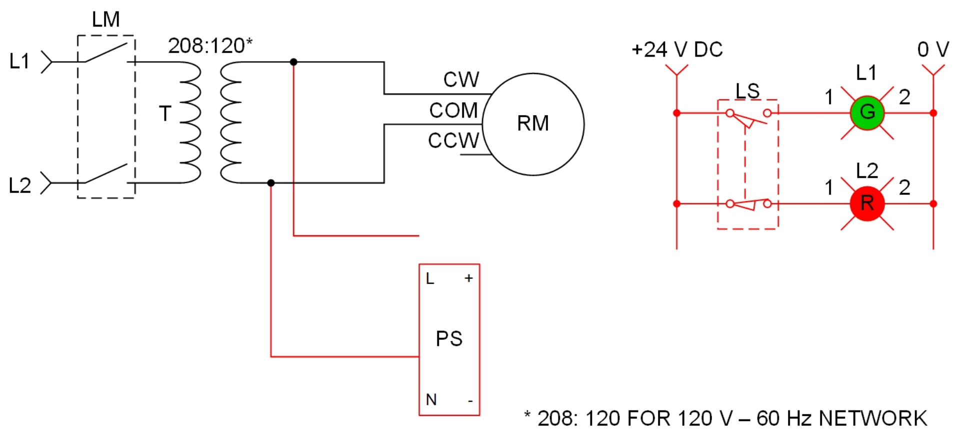
____

8. Validate your answer by setting and testing the circuit.

9. Turn off the Lockout Module.

10. Install the Limit Switch as described in the Discussion.

Set up the circuit shown in Figure 37.



* 208: 120 FOR 120 V – 60 Hz NETWORK
380: 110 FOR 220 V – 50 Hz NETWORK
415: 110 FOR 240 V – 50 Hz NETWORK
380: 120 FOR 220 V – 60 Hz NETWORK

LEGEND

L1 = PILOT LIGHT (GREEN)
L2 = PILOT LIGHT (RED)
LM = LOCKOUT MODULE
LS = LIMIT SWITCH
PS = DC POWER SUPPLY
RM = REVERSIBLE MOTOR (SINGLE PHASE)
T = CONTROL VOLTAGE TRANSFORMER

Figure 37. Circuit used to detect the presence of hole(s) in the disks.

11. Turn on the Lockout Module.

12. Does the green pilot light turn on and the red pilot light turn off when the Limit Switch is activated?

❑ Yes ❑ No

13. Does this confirm the operation of the contacts shown on the faceplate of the Limit Switch module?

❑ Yes ❑ No

14. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

Conclusion

In this exercise, you observed the ability of the sensors supplied with your training system to detect the presence of holes in three disks having different characteristics.

You also became familiar with the operation of the Limit Switch by using a disk mounted on the Reversible AC Motor shaft.

REVIEW QUESTIONS

1. What is the direction of rotation of the Reversible AC Motor?

   ____

   ____

   ____

2. The Inductive Proximity Switch is not capable of detecting holes in the fiber disk.

   ❑ True ❑ False

3. The Capacitive Proximity Switch is capable of detecting holes in the transparent plastic disk.

   ❑ True ❑ False

4. The Background Suppression Photoelectric Switch is not capable of detecting holes in the fiber disk.

   ❑ True ❑ False

5. The Polarized Retroreflective Photoelectric Switchs is not capable of detecting holes in the metallic disk if a depolarizing retroreflective surface is present behind the holes.

   ❑ True ❑ False

PLC-Controlled Circuits Using Sensors (optional)

EXERCISE OBJECTIVE

- Implement circuits using sensors, the Programmable Logic Controller, and the Reversible AC Motor.

DISCUSSION

Sensors are used to perform many functions in automated manufacturing and material handling systems. They are used as inputs to the PLCs for counting, positioning, determining product orientation, sorting, and monitoring operations for example.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Set up and connections
- Equipment required
- Project 1 - motor speed
  Project description. Requirements. Equipment list. Schematic diagram of the circuit. Programmable Logic Controller. Circuit setup. Circuit approval.
- Project 2 - number of plugs per 15 motor rotations
  Project description. Requirements. Equipment list. Schematic diagram of the circuit. Programmable Logic Controller. Circuit setup. Circuit approval.
- Project 3 - change motor rotation direction every ten turns
  Project description. Requirements. Equipment list. Schematic diagram of the circuit. Programmable Logic Controller. Circuit setup. Circuit approval.

PROCEDURE

Set up and connections

In this exercise, you will design three circuits using sensors, the Programmable Logic Controller, and the Reversible AC Motor.

Referring to a project description, you will draw the schematic diagram, setup the circuit, and test the circuit.

Equipment required

The lists of equipment required for this exercise are shown in the Procedure.

Project 1 - motor speed

Project description

Your client desires to know the rotation speed of the Reversible AC Motor.

To do so, you will design a system that counts the number of motor rotations during one minute.

Requirements

- Use the Limit Switch to count the number of rotations performed by the motor during one minute.
- Measure the time and control the operation of the system using the Programmable Logic Controller module.
- The system is started by turning a selector on the Switches module.
- After one minute of operation, the system automatically stops.
- The number of motor rotations is displayed by the PLC (counter display).
- The counter of the PLC, used to count the number of motor rotations, is reset using a push button on the Switches module.
- Use the Interposing Relays and Contactor modules to supply the motor.

Equipment list

The equipment required to perform this project is shown in Table 15.

Table 15. Equipment list

Model	Description
3103 (or 8110 or 8134)	Industrial Controls Mobile Workstation
3112	Switches
3125	Lockout Module
3127-2	Contactor
3128	Programmable Logic Controller
3129	Interposing Relays
3138	Control Transformer
3139	DC Power Supply
3149	Limit Switch
3174-3	Reversible AC Motor
3196 (or 8821)	AC Power Supply
8951-8	Connection Leads
8951-E	Connection Leads
38503	Magnetic Labels

A schematic diagram and a ladder program are suggested in Appendix F. However, it is suggested that you design your own circuit and refer to the Appendix F only if necessary.

Schematic diagram of the circuit

Draw the schematic diagram of the circuit in Figure 38.

Figure 38. Schematic diagram of the circuit.

Programmable Logic Controller

Draw your ladder program in Figure 39.

Figure 39. Ladder program.

Enter your ladder program into the Programmable Logic Controller.

Circuit setup

Set up the circuit you designed. Identify the controls with magnetic labels.

Circuit approval

Test your circuit to make sure that it operates as desired by your client.

Once your circuit is approved, turn the individual power switch of the AC Power Supply off, then disconnect the circuit.

Project 2 - number of plugs per 15 motor rotations

Project description

Your client desires to know the number of plugs detected by a sensor during 15 motor rotations of the Reversible AC Motor.

To do so, you will design a system that counts the number of motor rotations during one minute.

Requirements

- Use the Background Suppression Photoelectric Switch to detect the hole near the center of the metallic disk. This sensor is used to count the number of motor rotations.

- Use the Capacitive Proximity Switch to detect the plastic plugs inserted in the holes in the periphery of the metallic disk.

- The operation of the system is controlled using the Programmable Logic Controller module.

- The system is started by turning a selector on the Switches module.

- After 15 motor rotations, the system automatically stops.

- The number of plugs detected during the fifteen rotations is displayed by the PLC (counter display).

- The counters of the PLC are simultaneously reset using a push button on the Switches module.

- Use the Interposing Relays and Contactor modules to supply the motor.

Equipment list

Table 16. Equipment list.

Model	Description
3103 (or 8110 or 8134)	Industrial Controls Mobile Workstation
3103-3 (or 8810 or 8134)	Mobile Workstation
3112	Switches
3125	Lockout Module
3127-2	Contactor
3128	Programmable Logic Controller
3138	Control Transformer
3129	Interposing Relays
3139	DC Power Supply
3174-3	Reversible AC Motor
3196 (or 8821)	AC Power Supply
6373-B	Background Suppression Photoelectric Switch
6376-B	Capacitive Proximity Switch
8951-8	Connection Leads
8951-E	Connection Leads
38503	Magnetic Labels

A schematic diagram and a ladder program are suggested in Appendix F. However, it is suggested that you design your own circuit and refer to the Appendix F only if necessary.

Schematic diagram of the circuit

Draw the schematic diagram of the circuit in Figure 40.

Figure 40. Schematic diagram of the circuit.

Programmable Logic Controller

Draw your ladder program in Figure 41.

Figure 41. Ladder program.

Enter your ladder program into the Programmable Logic Controller.

Circuit setup

Set up the circuit you designed. Identify the controls with magnetic labels.

Circuit approval

Test your circuit to make sure that it operates as desired by your client.

Once your circuit is approved, turn the individual power switch of the AC Power Supply off, then disconnect the circuit.

Project 3 - change motor rotation direction every ten turns

Project description

Your client desires that the rotation direction of the Reversible AC Motor changes every ten turns.

To do so, you will design a system that counts the number of motor turns and changes the rotation direction of the motor.

Requirements

- Select the Polarized Retroreflective Photoelectric Switch with the reflective block to detect the hole in the fiber disk. This sensor is used to count the number of motor rotations.
- The operation of the system is controlled using the Programmable Logic Controller module.
- The system is started/stopped by turning a selector on the Switches module.
- After ten motor rotations, the rotation direction changes.
- The number of motor rotation is displayed by the PLC (counter display).
- The counters of the PLC are automatically reset by the program.
- Use the Interposing Relays and Dual Contactors modules to supply the motor.

Equipment list

The equipment required to perform this project is shown in Table 17.

Table 17. Equipment list.

Model	Description
3103 (or 8110 or 8134)	Industrial Controls Mobile Workstation
3112	Switches
3119	Dual Contactors
3125	Lockout Module
3128	Programmable Logic Controller
3138	Control Transformer
3129	Interposing Relays
3139	DC Power Supply
3174-3	Reversible AC Motor
3196 (or 8821)	AC Power Supply
6374-B	Polarized Retroreflective Photoelectric Switch
6396	Reflective Block
8951-8	Connection Leads
8951-E	Connection Leads
38503	Magnetic Labels

A schematic diagram and a ladder program are suggested in Appendix F. However, it is suggested that you design your own circuit and refer to the Appendix F only if necessary.

Schematic diagram of the circuit

Draw the schematic diagram of the circuit in Figure 42.

Figure 42. Schematic diagram of the circuit.

Programmable Logic Controller

Draw your ladder program in Figure 43.

Figure 43. Ladder program.

Enter your ladder program into the Programmable Logic Controller.

Circuit setup

Set up the circuit you designed. Identify the controls with magnetic labels.

Circuit approval

Test your circuit to make sure that it operates as desired by your client.

Once your circuit is approved, turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you designed three circuits using the sensors as inputs to the Programmable Logic Controller.

You used the Reversible AC Motor to drive the disks and use the motor in both directions of rotation.

Equipment Utilization Chart

The following equipment is required to perform the exercises in this manual.

Equipment		Exercise							
Model	**Description**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
3103 (or 8110 or 8134)	Industrial Controls Mobile Workstation	1	1	1	1	1	1	1	1
3112	Switches								1
3115-A	Pilot Lights	1	1	1	1	1	1	1	
3119	Dual Contactors								1
3125	Lockout Module	1	1	1	1	1	1	1	1
3127-2	Contactor								1
3128	Programmable Logic Controller								1
3129	Interposing Relays								1
3138	Control Transformer							1	1
3139	DC Power Supply	1	1	1	1	1	1	1	1
3149	Limit Switch						1	1	1
3174-3	Reversible AC Motor							1	1
3196 (or 8821)	AC Power Supply	1	1	1	1	1	1	1	1
6373-B	Background Suppression Photoelectric Switch	1	1					1	1
6374-B	Polarized Retroreflective Photoelectric Switch	1		1				1	1
6375-B	Inductive Proximity Switch					1		1	
6376-B	Capacitive Proximity Switch	1			1			1	1
6396	Reflective Block	1	1	1	1	1		1	1
8951-8	Connection Leads	1	1	1	1	1	1	1	1
8951-E	Connection Leads	1	1	1	1	1	1	1	1
38503	Magnetic Labels								1
76768	Filler Pot				1				

Appendix B

Sensor Selection Guide

What to know when selecting a sensor

- Distances

  Between the sensor and the target: ______________________________

  Between the sensor and the background: _________________________

- Target

  Metallic or nonmetallic: _______________________________________

  Ferrous or non-ferrous: _______________________________________

  Opaque, transparent, translucent: _______________________________

  Dimensions: ____

  Movements: ____

- Mounting requirements: _______________________________________

- Environment

  Ambient operating temperature, dust, oil, humidity: _________________

- Supply voltage available: ______________________________________

- Response time: ____

- Sensor output type (load requirement) ____________________________

  Transistor, relay, triac: ____

Basic Setup and Lockout/Tagout Procedures

This appendix is divided into three sections:

- Basic Setup procedure explains the basic operations that must be performed at the beginning of the exercise procedures.
- Lockout/Tagout procedure (de-energizing procedure) describes the lockout/tagout procedure used to de-energize the Industrial Controls Training System before setting up a circuit.
- Energizing procedure gives details on how to end a lockout/tagout procedure and energize the Industrial Controls Training System.

Basic setup procedure

This procedure is recommended at the beginning of every experiment. It insures that the system is safe prior to cabling specific circuits.

1. Make sure that the power switch of the power supply is set to the off position.

   The power supply should already be installed in the workstation.

2. Install the Lockout Module in the workstation.

3. Turn off the Lockout Module.

4. Connect the Lockout Module leads to the power supply terminals, respecting the phase sequence.

Lockout/tagout procedure (de-energizing procedure)

1. Turn off the Lockout Module.

2. Install the lockout hasp and the student padlocks and tags on the Lockout Module. Ask the instructor to install the lab padlock and tag as well.

3. Check that the Lockout Module switch cannot be opened. With a voltmeter, verify that no voltage is present between the Lockout Module output terminals to confirm that the circuit is de-energized. You may now set up your circuit.

Energizing procedure

1. Connect the green chassis terminals (on the modules) to the earth (ground) terminal of the Lockout Module.

2. Make sure the security guard is installed if you are using a motor.

3. Identify the push buttons, selector switches, and pilot lights with magnetic labels in accordance with the circuit schematic diagram.

4. Once the connections are made, ask for the instructor to check the circuit. When the circuit is correctly wired, notify all the people working around the workstation that the system will be energized.

5. Remove the lockout hasp, padlocks and tags.

   If you are using the Power Supply, Model 8821, make sure that the voltage control knob is set to 0%.

   AC and DC voltages (fixed or variable) are available on the Power Supply, Model 8821. For all exercises requiring AC voltage, use the AC variable output (terminals 4, 5 and 6).

6. Turn on the power supply and Lockout Module, and return to your exercise.

   If you are using the Power Supply, Model 8821, set the voltage control knob to 100%.

Care of the Sensors Training System

- Keep the training system clean and dry. If, for some reason, water, oil, or another liquid is dropped or splashed on a sensor, wipe it off immediately with a damp cloth. Do not use strong cleansers of any kind on the sensors.

- Manipulate the sensors carefully. Many of them are delicate in nature and must be handled with care.

- Report any damaged or missing parts to your instructor immediately.

Electromagnetic Spectrum

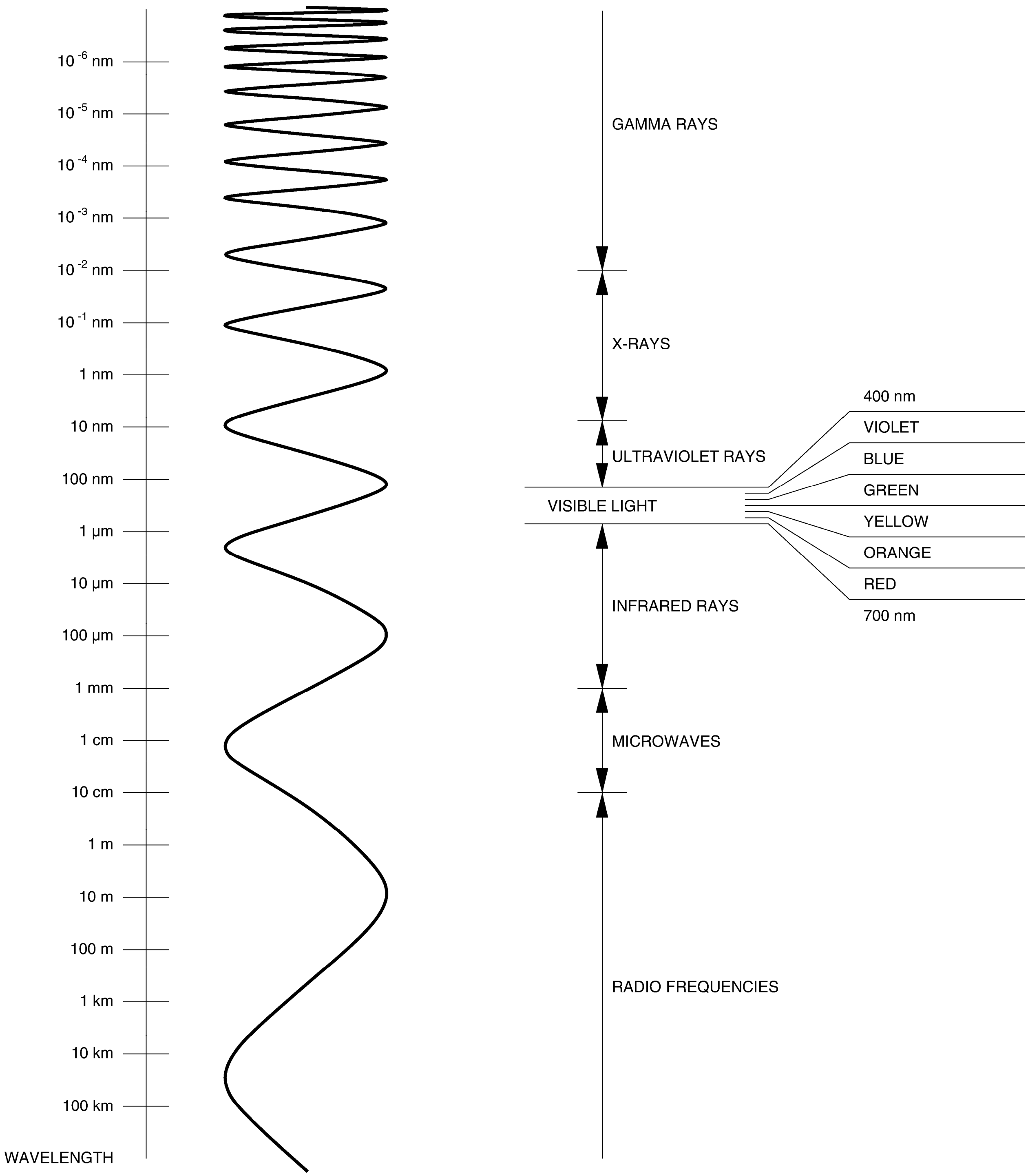
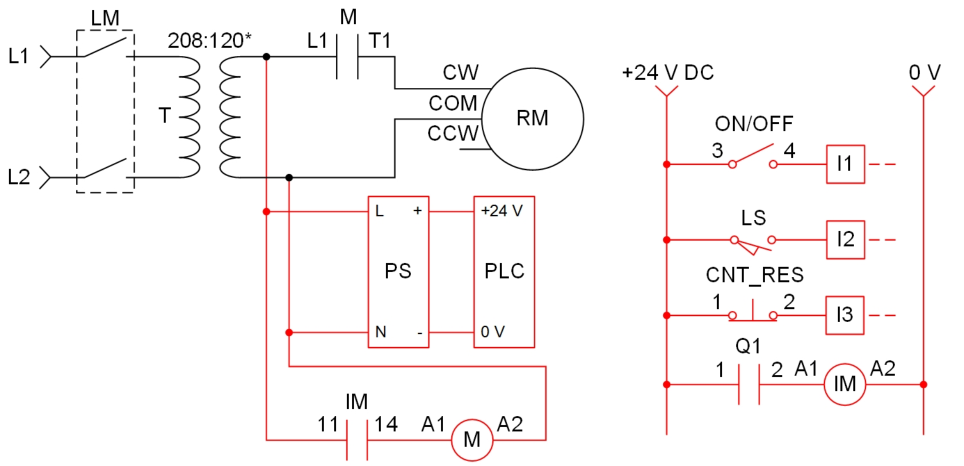


Figure 44. Electromagnetic spectrum.

Suggested Schematic Diagrams and Ladder Programs

This appendix provides suggested schematic diagrams and ladder programs for the projects proposed in Exercise 8. As mentioned, it is suggested that you design your own circuits and refer to this appendix only if necessary.



* 208: 120 FOR 120 V – 60 Hz NETWORK
380: 110 FOR 220 V – 50 Hz NETWORK
415: 110 FOR 240 V – 50 Hz NETWORK
380: 120 FOR 220 V – 60 Hz NETWORK

LEGEND

CNT_RES = COUNTER RESET PUSH BUTTON (MOMENTARY CONTACT)
Ix = PLC INPUT #x
IM = INTERPOSING RELAY FOR MAIN CONTACTOR (24 V DC COIL)
LS = LIMIT SWITCH
M = MAIN CONTACTOR
ON/OFF = ON/OFF SELECTOR SWITCH (MAINTAINED CONTACT)
PLC = PROGRAMMABLE LOGIC CONTROLLER
PS = DC POWER SUPPLY
Qx = PLC OUTPUT RELAY #x
RM = REVERSIBLE MOTOR (SINGLE PHASE)
T = CONTROL VOLTAGE TRANSFORMER

Figure 45. Suggested schematic diagram for Project (Figure 38).

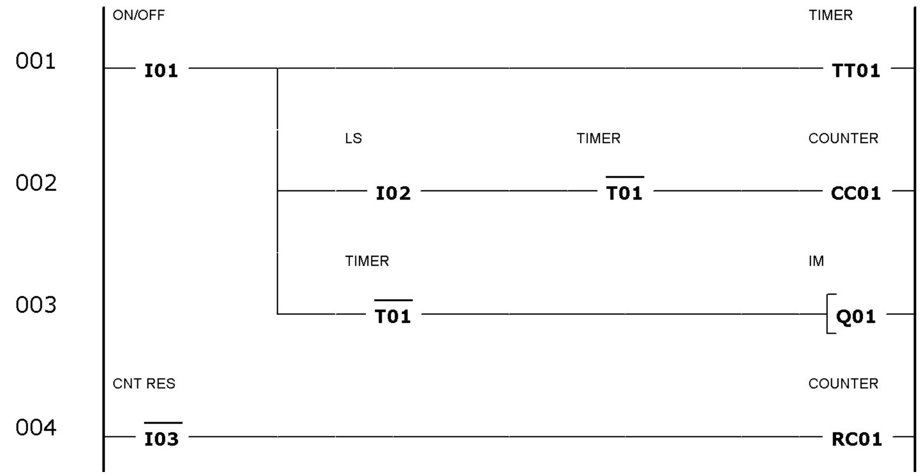
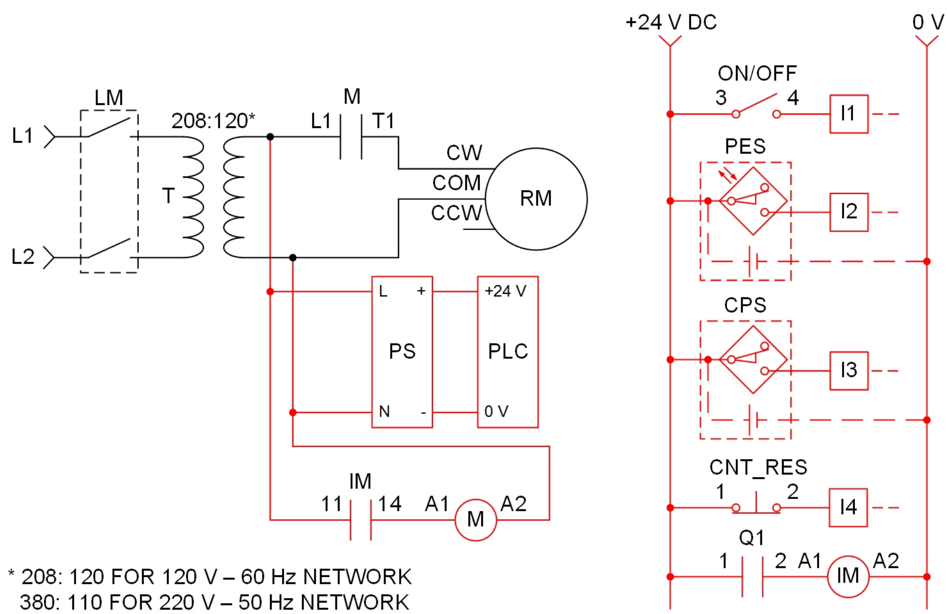


Figure 46. Suggested ladder program for Project 1 (Figure 39).



* 208: 120 FOR 120 V – 60 Hz NETWORK
380: 110 FOR 220 V – 50 Hz NETWORK
415: 110 FOR 240 V – 50 Hz NETWORK
380: 120 FOR 220 V – 60 Hz NETWORK

LEGEND

CNT_RES	=	COUNTER RESET PUSH BUTTON (MOMENTARY CONTACT)
CPS	=	CAPACITIVE PROXIMITY SWITCH
Ix	=	PLC INPUT #x
IM	=	INTERPOSING RELAY FOR MAIN CONTACTOR (24 V DC COIL)
M	=	MAIN CONTACTOR
ON/OFF	=	ON/OFF SELECTOR SWITCH (MAINTAINED CONTACT)
PES	=	BACKGROUND SUPPRESSION PHOTOELECTRIC SWITCH
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
RM	=	REVERSIBLE MOTOR (SINGLE PHASE)
T	=	CONTROL VOLTAGE TRANSFORMER

Figure 47. Suggested schematic diagram for Project 2 (Figure 40).

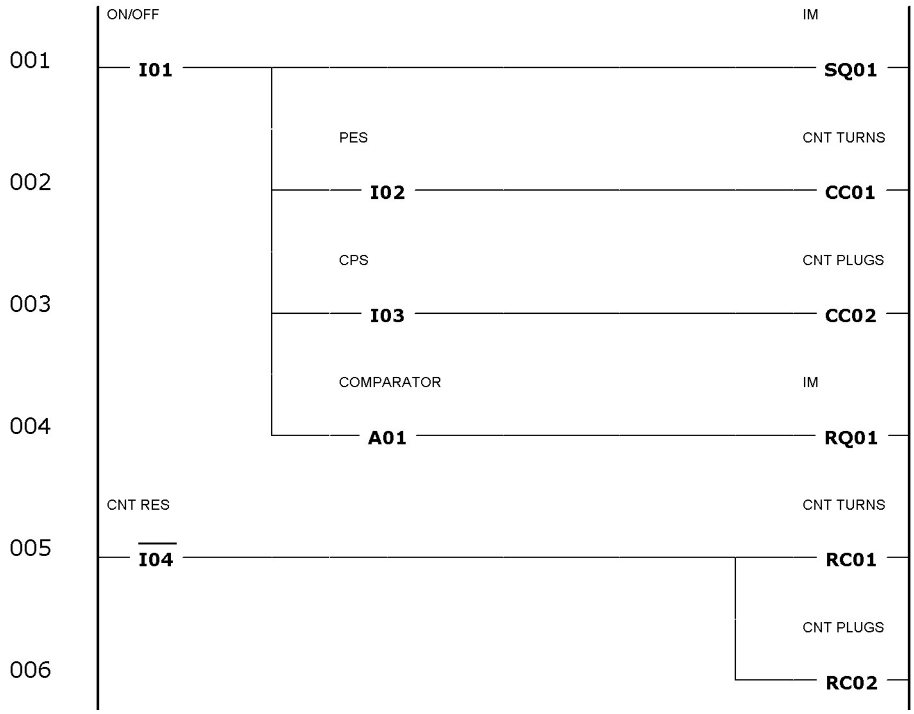
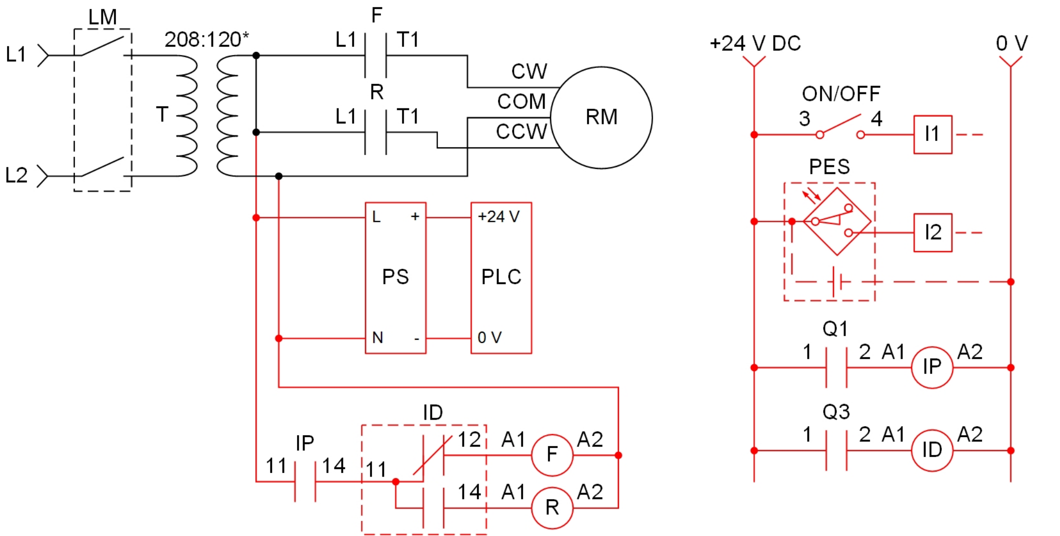


Figure 48. Suggested ladder program for Project 2 (Figure 41).



* 208: 120 FOR 120 V – 60 Hz NETWORK
380: 110 FOR 220 V – 50 Hz NETWORK
415: 110 FOR 240 V – 50 Hz NETWORK
380: 120 FOR 220 V – 60 Hz NETWORK

LEGEND

F	=	FORWARD DIRECTION CONTACTOR
Ix	=	PLC INPUT #x
ID	=	INTERPOSING RELAY FOR MOTOR DIRECTION (24 V DC COIL)
IP	=	INTERPOSING RELAY FOR MOTOR POWER (24 V DC COIL)
ON/OFF	=	ON/OFF SELECTOR SWITCH (MAINTAINED CONTACT)
PES	=	BACKGROUND SUPPRESSION PHOTOELECTRIC SWITCH
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
R	=	RESERVE DIRECTION CONTACTOR
RM	=	REVERSIBLE MOTOR (SINGLE PHASE)
T	=	CONTROL VOLTAGE TRANSFORMER

Figure 49. Suggested schematic diagram for Project 3 (Figure 42).

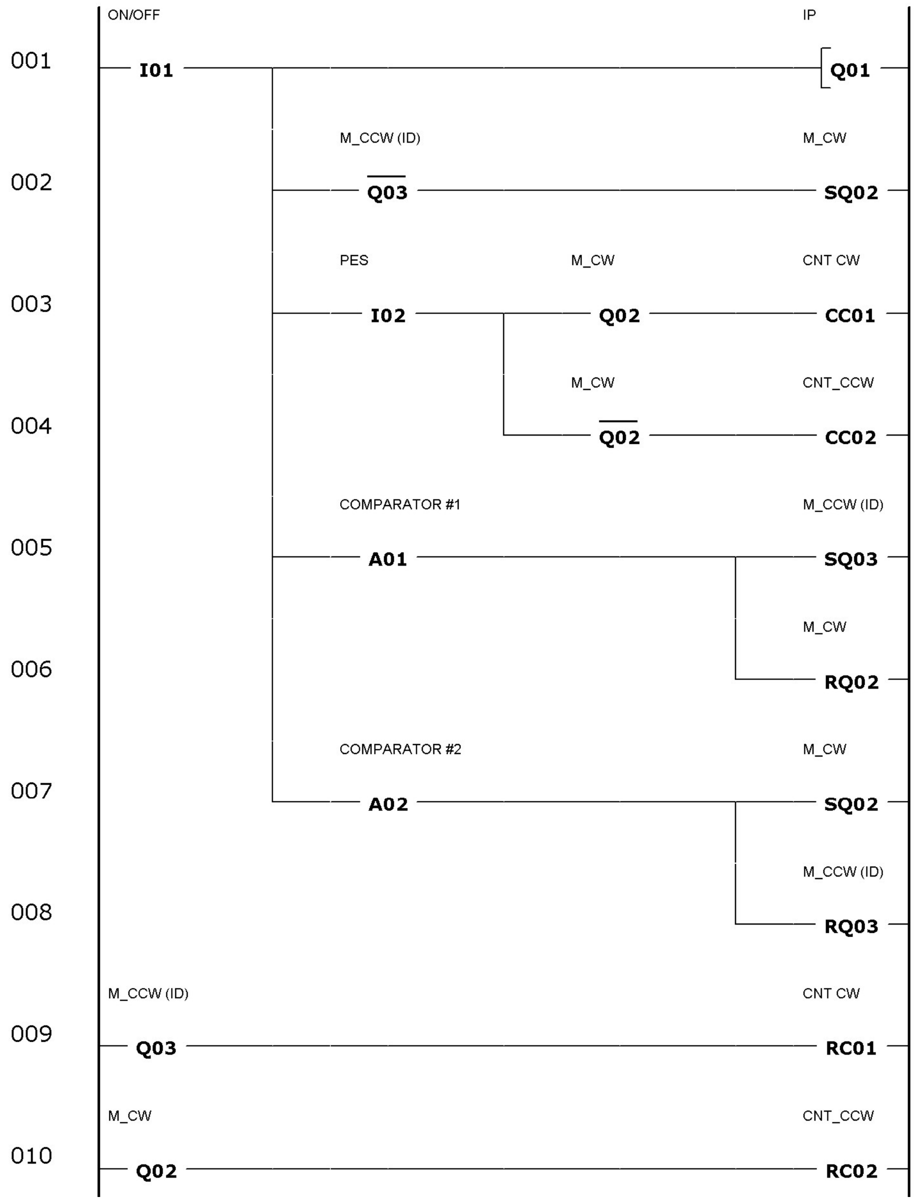


Figure 50. Suggested ladder program for Project 3 (Figure 43).

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