Exercise 1

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.

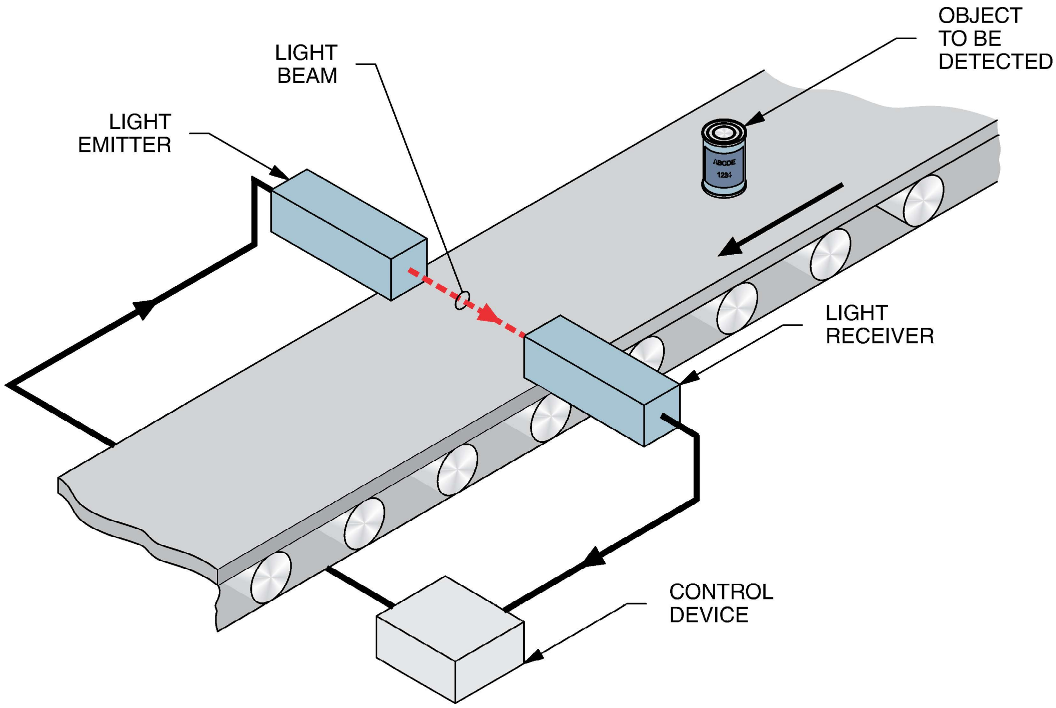


Figure 1. Typical photoelectric application.

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.

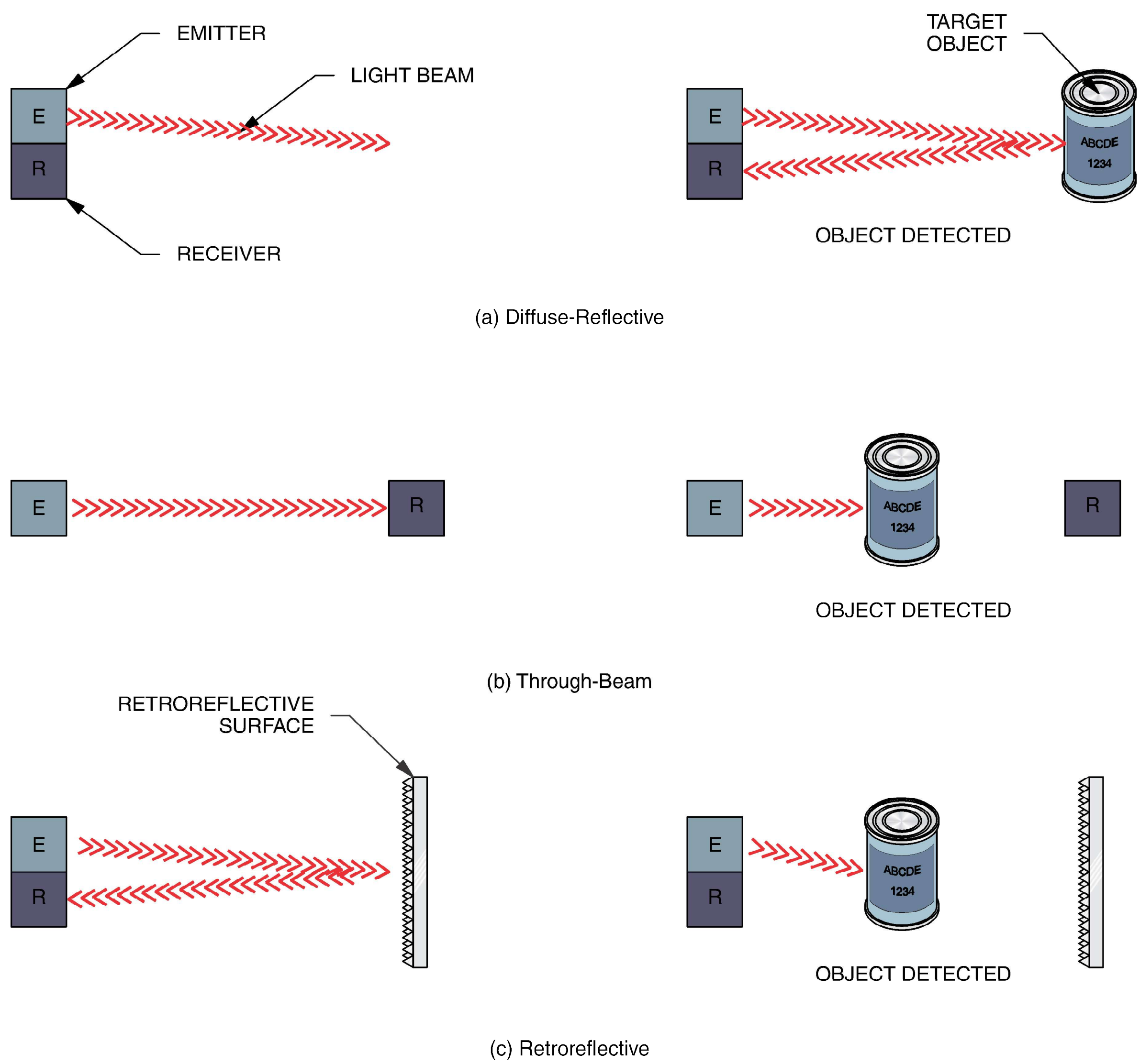


Figure 2. Photoelectric sensing modes.

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).

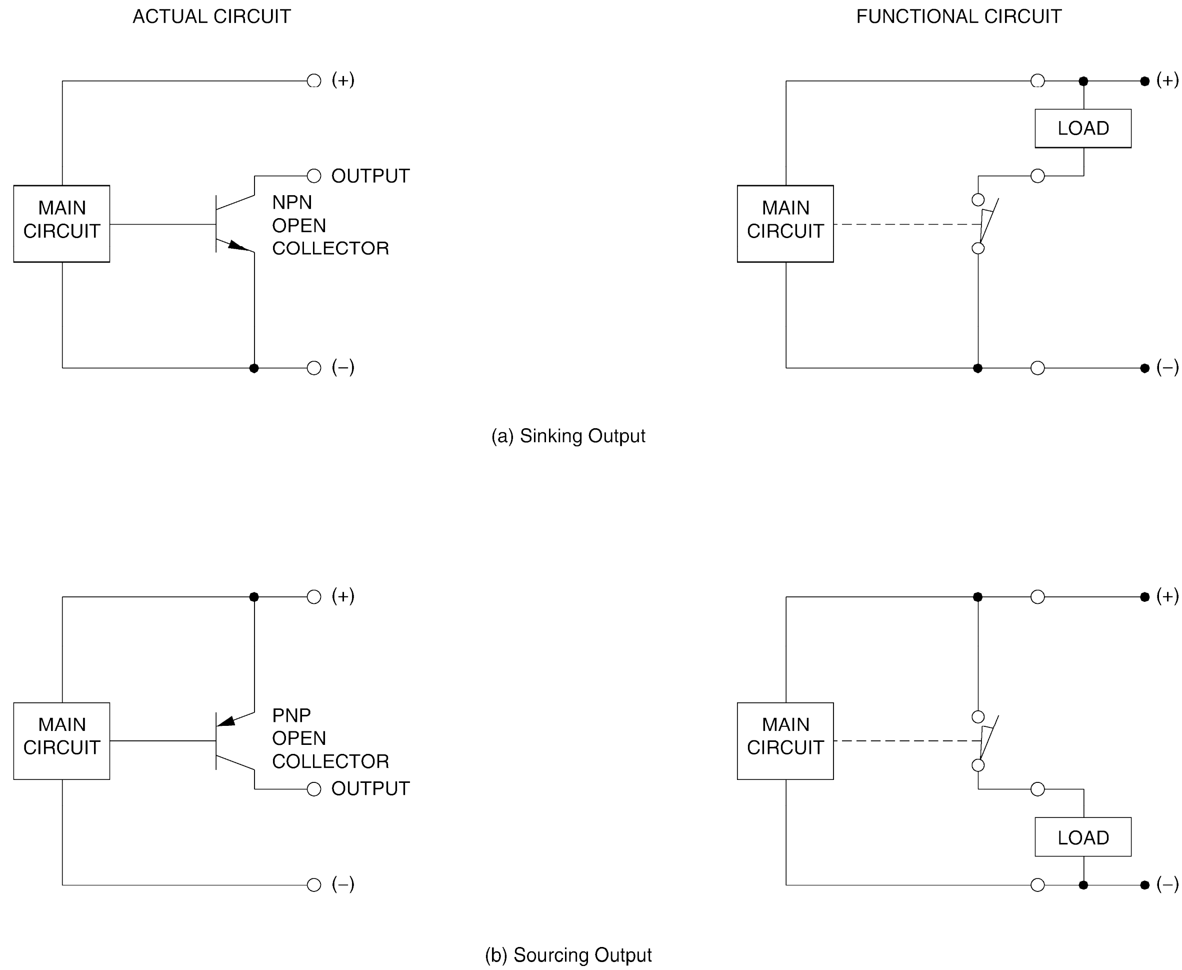


Figure 3. Transistor output.

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.

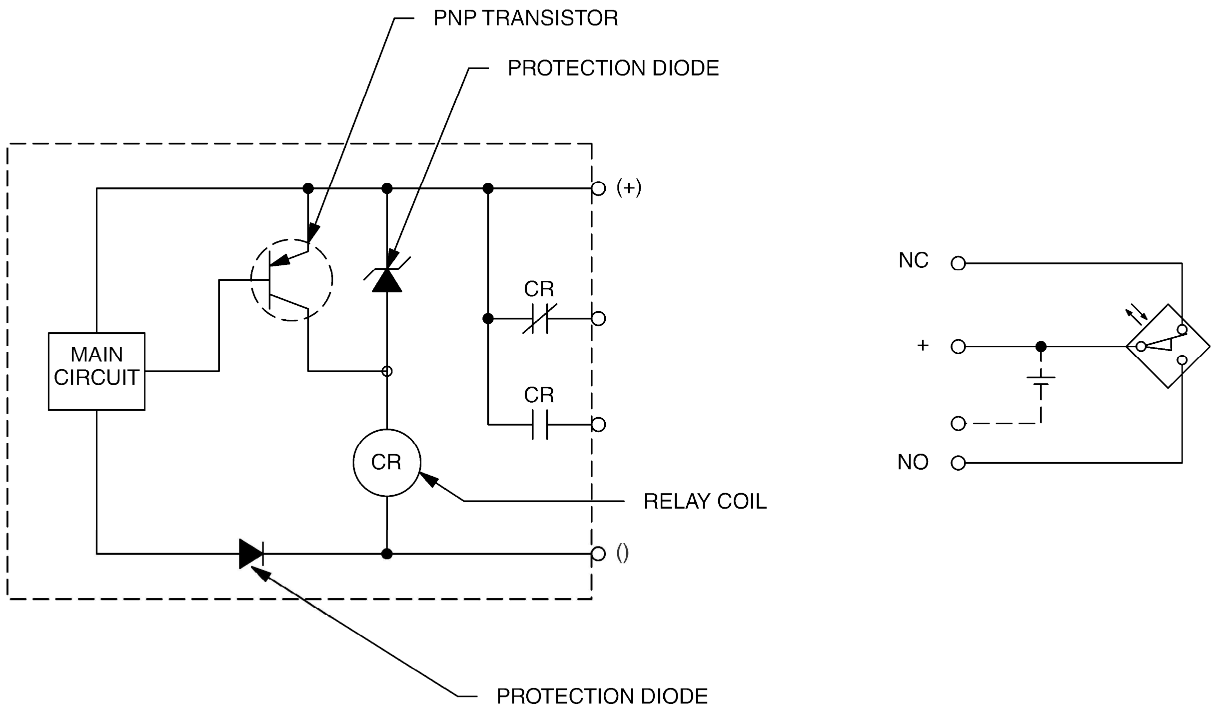


Figure 4. Relay output.

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.

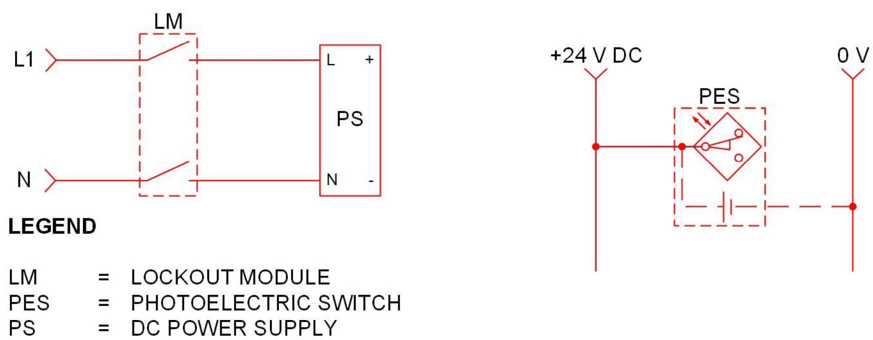


Figure 5. Circuit used to determine if the sensors use a visible or infrared light beam.

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

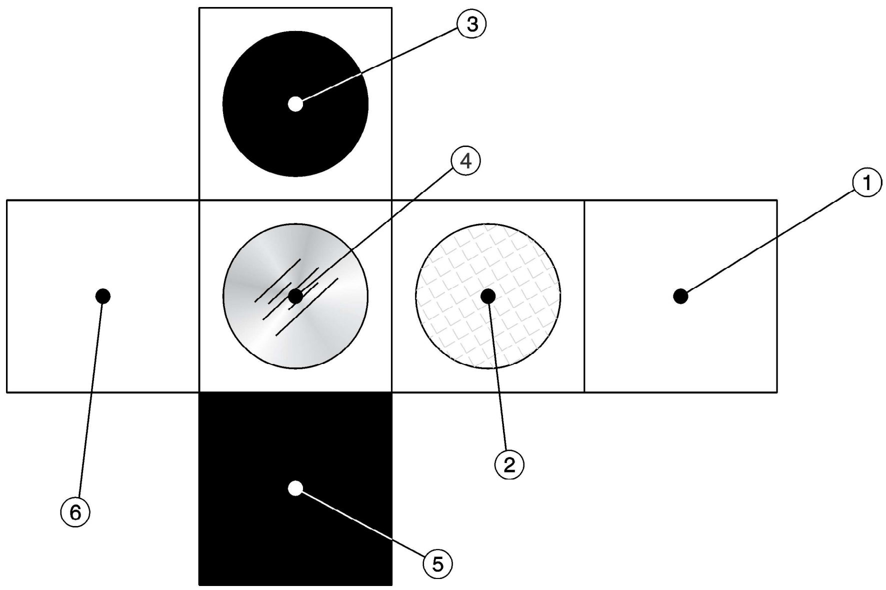
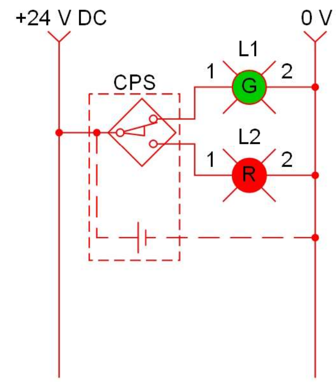


Figure 6. Development view of the Reflective Block

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.



LEGEND

L1 = PILOT LIGHT (GREEN)
L2 = PILOT LIGHT (RED)
CPS = CAPACITIVE PROXIMITY SWITCH

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?