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.

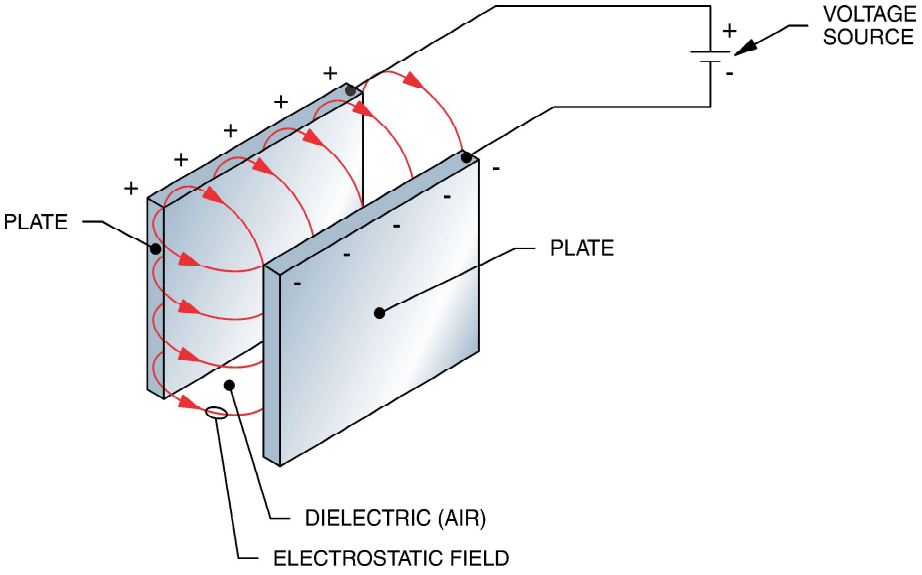

Figure 17. Charged capacitor.

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.

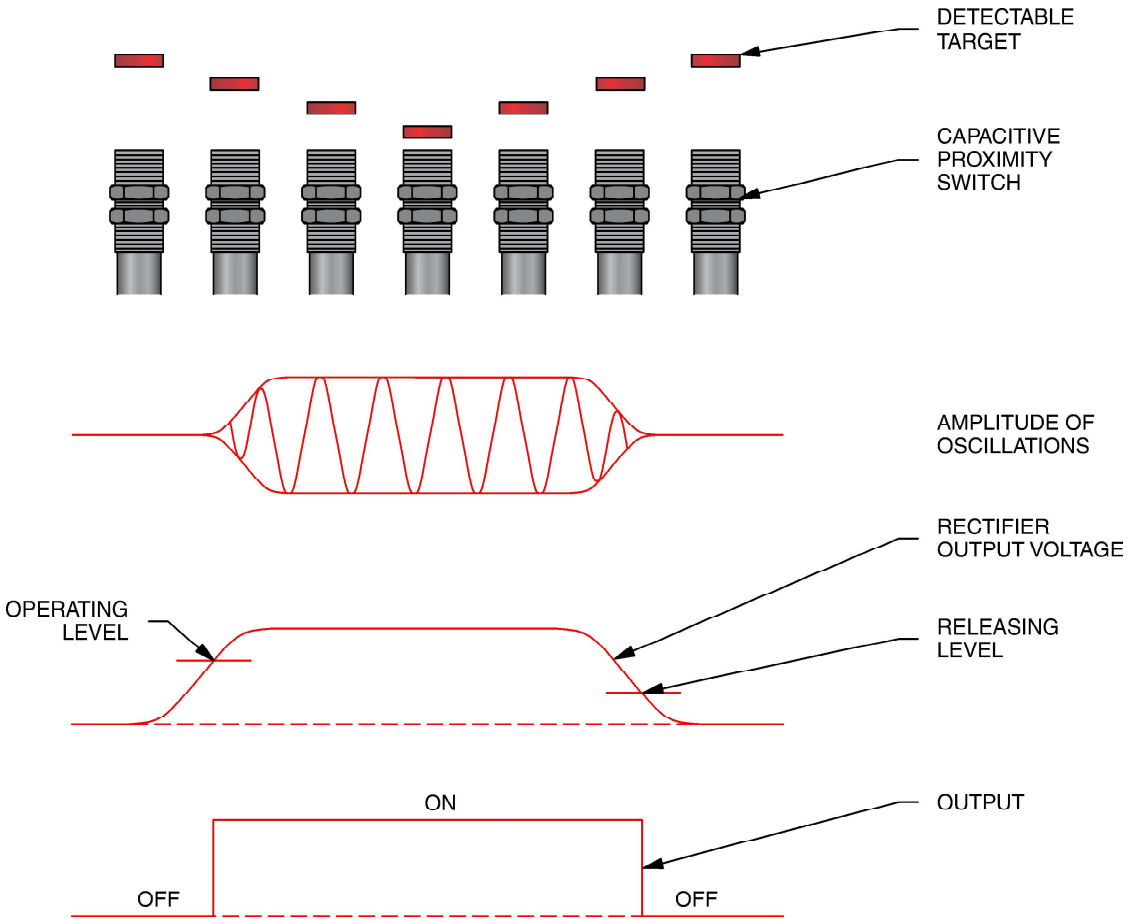

Figure 18. Operation of a capacitive proximity sensor.

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.

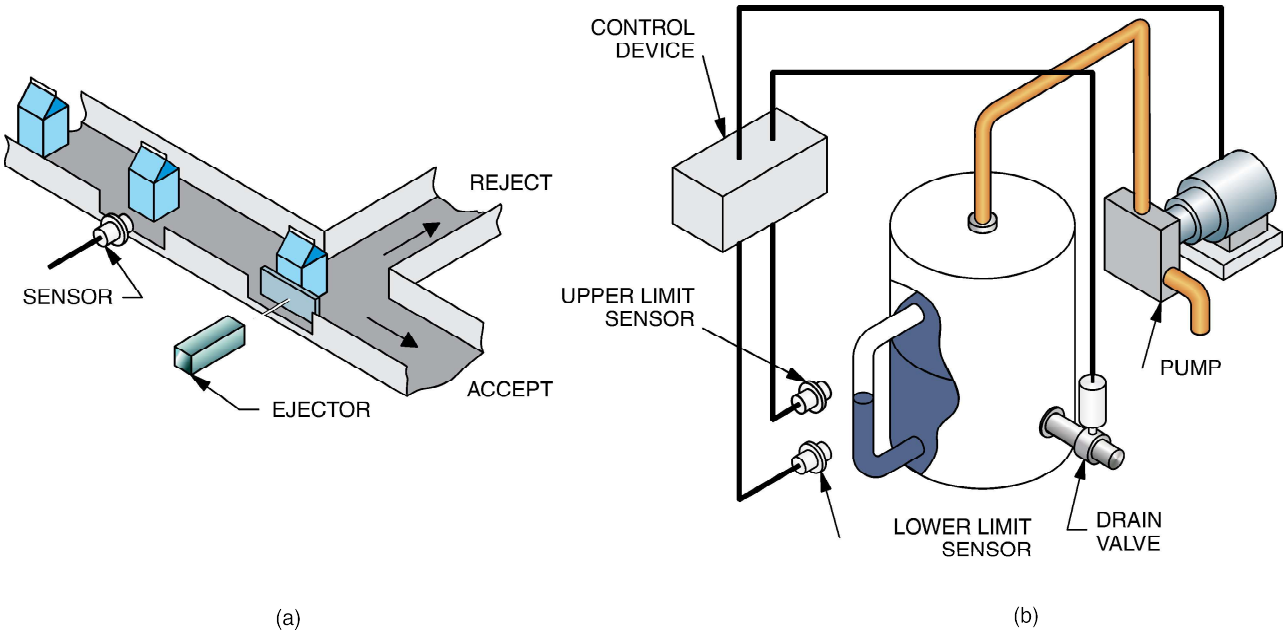

Figure 19. Sensing liquid level using capacitive proximity switches.

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.

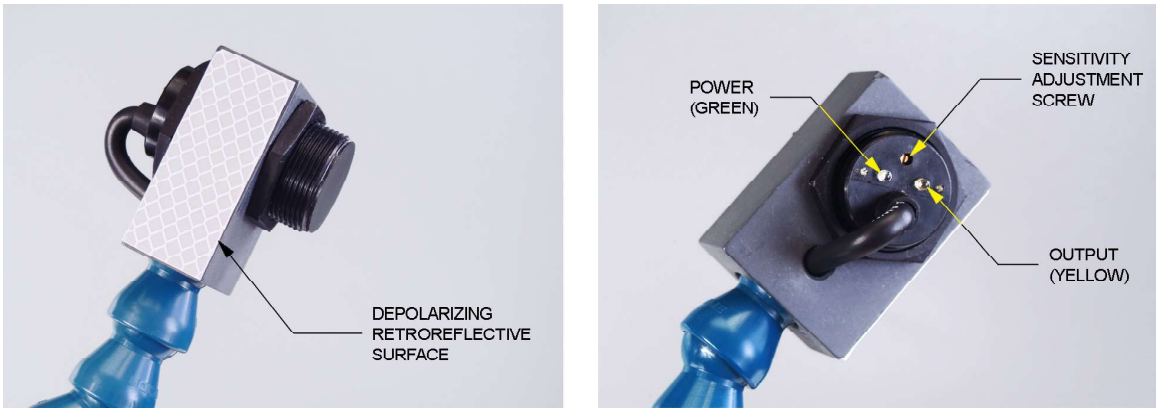

Figure 20. Capacitive Proximity Switch.

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.

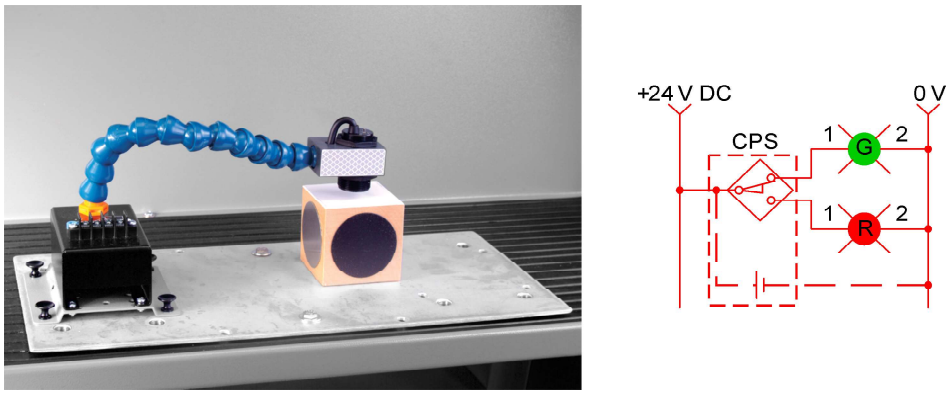

Figure 21. Circuit using the Capacitive Proximity Switch.

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.

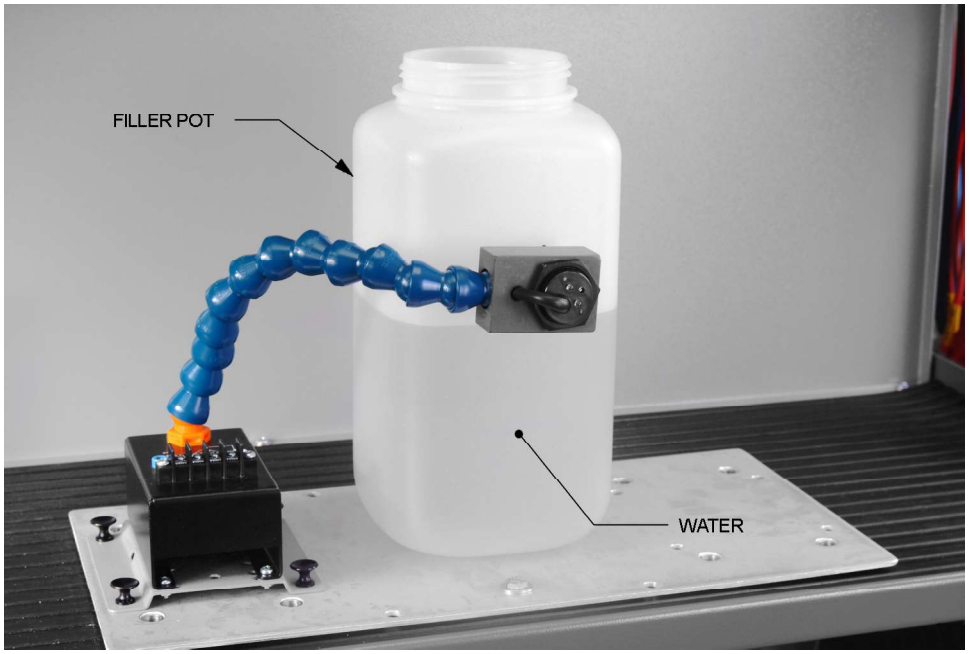

Figure 22. Liquid detection using the Capacitive Proximity Switch.

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.