Introduction to Sensors

EXERCISE OBJECTIVE

• When you have completed this exercise, you will be introduced to photoelectric, capacitive and inductive sensors;
• You will also be introduced to the terms commonly used in the sensor field;
• You will become familiar with the components of your Sensors Training System.

DISCUSSION

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: they can count, sense height or size, position, monitor operating speeds, and much more. Figure 1-1 shows a typical photoelectric application.
Introduction to Sensors

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 G.

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.

Unwanted effects of stray light on sensor operation can be reduced by modulating the frequency of the light beam. If the light beam were not frequency modulated, bright light of 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 1-2 shows how each mode works.

In the diffuse-reflective sensing mode, as shown in Figure 1-2 (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, as shown in Figure 1-2 (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 the longest sensing distances (more than 250 m (820 ft). These sensors are well suited to operate in very dusty or dirty industrial environments, but may be not suitable to detect translucent or transparent targets since the receiver will see through this type of target.
Introduction to Sensors

Figure 1-2. Photoelectric sensing modes.

In the retroreflective sensing mode, as shown in Figure 1-2 (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.

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 non-metallic objects while inductive sensors detect the presence of metallic objects only. Their operation is discussed in Exercises 6 and 7.
Excess Gain Ratio, Operating Margin, Margin

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 "operate point" (where a detected target causes the sensor output to switch to the activated mode) and the "release 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 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

Transistor Output

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

Sinking transistor output is a transistor output that requires the load to be connected between the sensor output and the positive power connection as shown in Figure 1-3 (a). A current sink output requires an NPN transistor. This output configuration can operate directly low-voltage logic circuitry (as transistor-transistor logic, TTL).
Introduction to Sensors

Figure 1-3. Transistor output.

Sourcing transistor output is a transistor output that requires the load to be connected between the sensor output and the negative power connection as shown in Figure 1-3 (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. The sensors of your training system are of the PNP transistor output type.

**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 1-4. 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.

![ Relay output diagram ]

**Figure 1-4. Relay output.**

**Triac Output**

The triac output is another type of sensor output. It is a solid-state device designed for AC switching only. Triacs offer high switching current, making them suitable for connection to large contactors and solenoids. They are not subject to the mechanical limitations of relays and their life expectancy is virtually infinite.

**Note:** 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 object. The sensors act as switches, activated by targets, rather than transducers whose output is proportional to an input signal.

**Sensor Selection Guide**

A **Sensor Selection Guide** is supplied in Appendix B. It shows many parameters that must be considered when selecting a sensor.
Introduction to Sensors

Procedure Summary

In the first part of the exercise, Photoelectric Switches, you will determine which photoelectric switches, of your training system, use visible red light and infrared light as light sources.

In the second part of the exercise, Characteristics of the Reflective Block, you will determine the characteristics of each surface of the Reflective Block of your training system.

In the third part of the exercise, Switch Operation, 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 of this manual, to obtain the list of equipment required to perform this exercise.

PROCEDURE

Photoelectric Switches

1. There are four photoelectric switches in your Sensors Training System: the Diffuse Reflective Photoelectric Switch Model 6377, the Background Suppression Photoelectric Switch Model 6373, the Fiber-Optic Photoelectric Switch Model 6378, and the Polarized Retroreflective Photoelectric Switch Model 6374.

Three of them use a visible red light beam and the other uses an infrared light beam. One sensor at a time, connect the positive (+) and negative (-) terminals of the photoelectric switch to the corresponding terminals of the DC Power Supply.

Turn on the DC Power Supply, and determine if the sensor you are observing uses a visible red or 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 1-1.

Note: Infrared light is harmless to the human eye.
Introduction to Sensors

<table>
<thead>
<tr>
<th>PHOTOELECTRIC SENSORS</th>
<th>VISIBLE RED</th>
<th>INFRARED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse Reflective Photoelectric Switch Model 6377</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Background Suppression Photoelectric Switch Model 6373</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber-Optic Photoelectric Switch Model 6378</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polarized Retroreflective Photoelectric Switch Model 6374</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1-1. Visible Red and Infrared Light Beams.

☐ 2. Turn off the DC Power Supply.

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 1-5.

- Black Plastic Surface
- Matte Black Metallic Surface
- Shiny Metallic Surface
- White Plastic Surface

![Figure 1-5. Development view of the Reflective Block.](image)

Switch Operation

☐ 4. Get the Capacitive Proximity Switch, Model 6376, and connect the circuit shown in Figure 1-6.
Introduction to Sensors

Figure 1-6. Circuit using the Capacitive Proximity Switch.

☐ 5. Clamp the switch to the work surface. Connect the (+) and (-) terminals of the switch to the corresponding terminals of the DC Power Supply. Turn on the DC Power Supply.

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

☐ 6. Is lamp L1 turned off, suggesting the output transistor of the Capacitor Proximity Switch is not activated?

☐ Yes ☐ No

☐ 7. Move a finger back and forth about 6 mm (0.25 in) in front of the sensor. Does the lamp L1 light? Explain why.

____________________________________________________________________________________

____________________________________________________________________________________

☐ 8. What happens to lamp L2 when lamp L1 turns on? Explain why.

____________________________________________________________________________________

____________________________________________________________________________________
CONCLUSION

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

You determined which photoelectric switches, of your training system, use visible red light and infrared light as a 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?
Introduction to Sensors

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

____________________________________________________

____________________________________________________

____________________________________________________