Occupancy Sensor Placement and Technology

Best Practices

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This document was written by the Technical Publications department at Crestron.

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Introduction

A lighting control system relies heavily on the ability to sense the presence of people in controlled spaces; occupancy sensors are used for this purpose. Occupancy sensors use a variety of technologies to detect the motion and presence of people.

Make sure to understand the limitations of the technology before deploying a lighting management system that uses occupancy sensors. This document outlines the technology used in Crestron® occupancy sensors and provides guidance on avoiding false tripping and vacancy situations. This document also provides guidance on occupancy sensor placement in a variety of room types.

Occupancy Sensor Technology

There are two primary technologies used in occupancy sensors: passive infrared (PIR) and ultrasonic. These two technologies have different strengths and weaknesses associated with their use. This section describes the limitations of PIR and ultrasonic technologies.

Passive Infrared

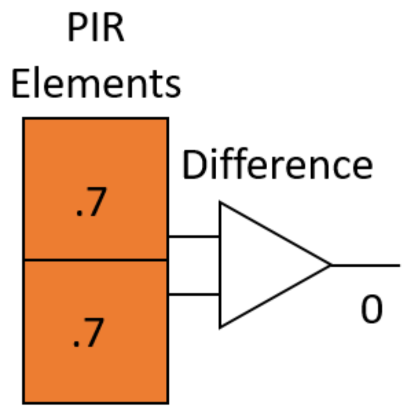
Passive infrared is a passive technology and does not emit any energy into the space. This passive nature is why battery powered sensors are usually of the PIR type. The principle behind PIR is that all objects give off infrared radiation in the form of heat; the PIR sensor can detect this heat and determine that there is motion in the room.

The fact that all objects emit heat is important; however, it does not accurately describe the complexity of a PIR sensor. Most PIR sensors only have a small number of sensing elements, typically four for an in-ceiling sensor. Think of this as a four-pixel camera; it would be very difficult to understand what is happening in an image taken by such a camera since all information coming into the sensor distills into four data points.

PIR sensors do not just detect heat, they use a differential pair and a Fresnel lens to detect motion occurring in a space. A differential pair of PIR sensors detects changes independently.

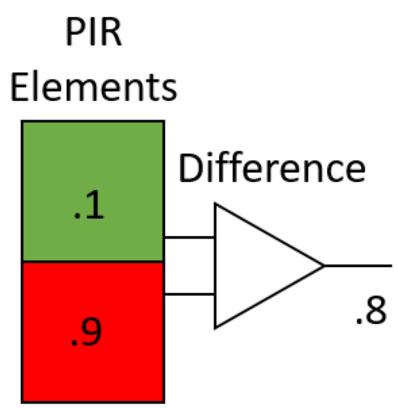
The example below shows that a general rise in the room's temperature is not detected.

Sensor Detecting No Change in Temperature



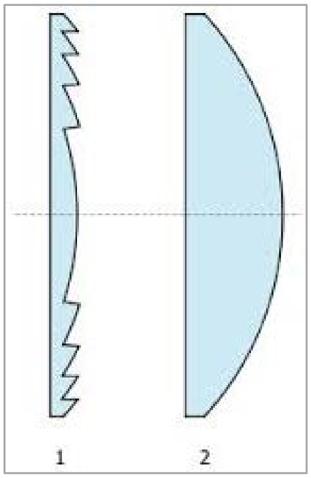
When one sensor sees a unique increase or decrease in incident infrared radiation, the sensor reports it to the other sensor as motion. The amount of difference detected by the PIR sensor pairs is effectively the sensitivity of the sensor. The number can be manipulated to remove false detection by pets and smaller objects moving through the space.

Sensor Detecting Change in Temperature



The differential pair is useless without a lens to focus the infrared energy toward the sensing elements. The Fresnel lens does the focusing and achieves a particular focal length with a physically smaller lens than would typically be required. A good visualization would be a lighthouse. The lighthouse has a large lens with a long focal length, which requires an unreasonably large or heavy piece of glass to achieve the lensing effect. The Fresnel lens solves this problem through a unique construction of the glass.

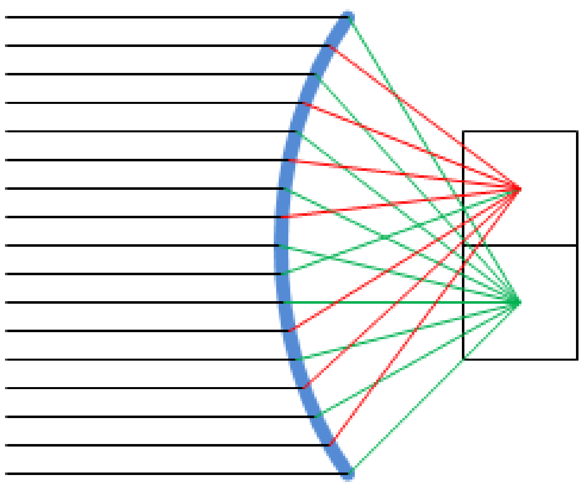
Fresnel Lens (1) and Convex Lens (2)



Lens 1 is physically smaller but achieves the same focal length as lens 2. In motion sensors, the Fresnel lens creates multiple focus points.

In a PIR motion sensor, the Fresnel lens works so that two parallel rays focus onto two different IR sensors, as shown in the example below. This means that when a warm body walks through two zones of the Fresnel lens, a large differential on the PIR elements indicates the space is occupied.

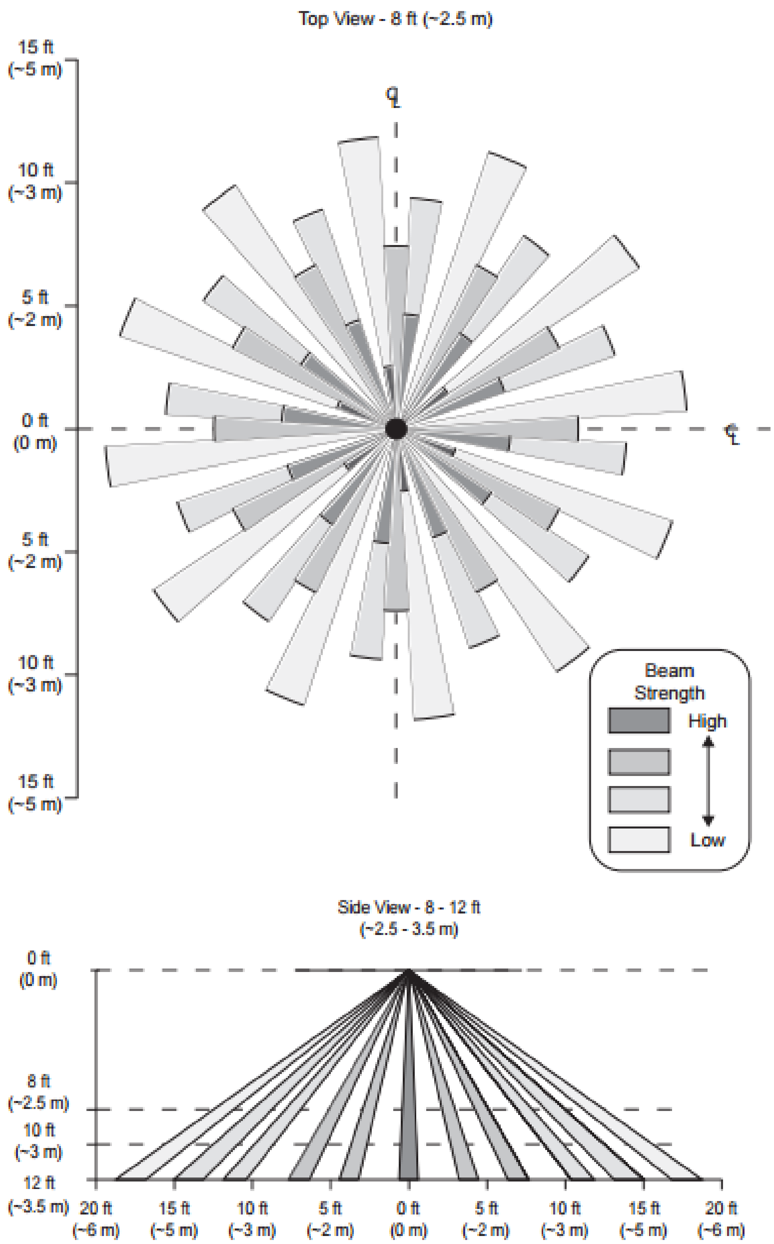
PIR Motion Sensor and Fresnel Lens Example



Placement and Motion Type

Determining how the sensor will react to a space involves understanding PIR technology. PIR sensors come with a coverage area diagram that details exactly how the Fresnel lens is designed. Refer to the examples below.

PIR Sensor Coverage Area Diagrams



The same-shaded area of these diagrams indicates that a lens facet covers this space. As discussed above, motion is detected within the coverage pattern. Therefore, if a person moves only through the light gray portion of the coverage area, the motion is not significant enough, or the motion is such that there is no transition between lens facets, so the sensor cannot register motion. In these scenarios, it is also important to note that increasing sensitivity will not improve the performance of the sensor.

PIR Sensor False Triggers

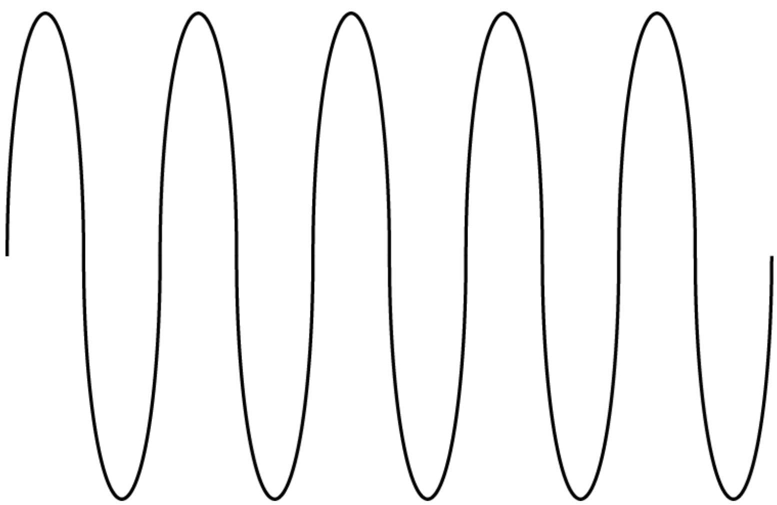
PIR sensors utilize infrared radiation impinging on the sensor to detect motion. A change in temperature in the space can result in an erroneous reading from the sensor. HVAC vents that cause moving air across the sensor, or situations that cause the sensor housing to heat up and cool down, will cause false triggers. Sensitivity settings can be manipulated to help alleviate some airflow or localized heating and cooling, but the correct solution is to move the sensor.

Ultrasonic [US]

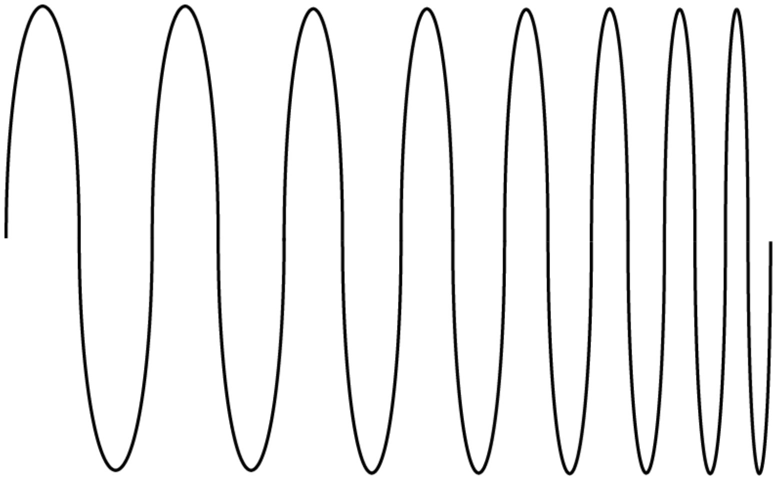
Ultrasonic sensors, unlike PIR sensors, do emit energy into the space and make use of the Doppler effect in order to detect motion. The Doppler effect describes the phenomenon we experience when a moving sound source passes us. For example, when we hear the siren of an approaching police car, the apparent pitch or frequency of the siren changes, increasing as the siren gets closer. This is because the emitted sound waves from the siren are effectively being compressed—occurring closer together—as the car approaches. Then, after the police car passes, the sound waves are effectively being expanded—occurring farther apart—so the apparent pitch of the siren decreases.

Ultrasonic sensors exploit the Doppler effect by “listening” to reflected sounds. Each sensor uses a speaker and a microphone. The speaker emits a short burst of energy at a specific frequency (approximately 42 kHz, which is well above the audible range for humans). The microphone then listens for the reflections of that sound from objects within the space. If the reflected sound has the same frequency as the burst emitted by the sensor, objects within the space are not in motion relative to the sensor. If there are reflections that are increasing in frequency, there is movement toward the sensor. If there are reflections that are decreasing in frequency, there is movement away from the sensor.

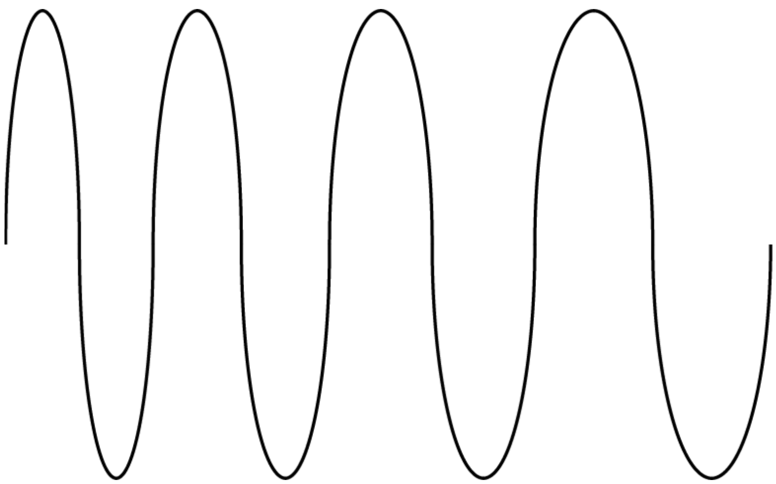
Reflections at Same Frequency Emitted by Sensor – No Motion



Reflections Increasing in Frequency – Motion Toward Sensor



Reflections Decreasing in Frequency – Motion Away from Sensor

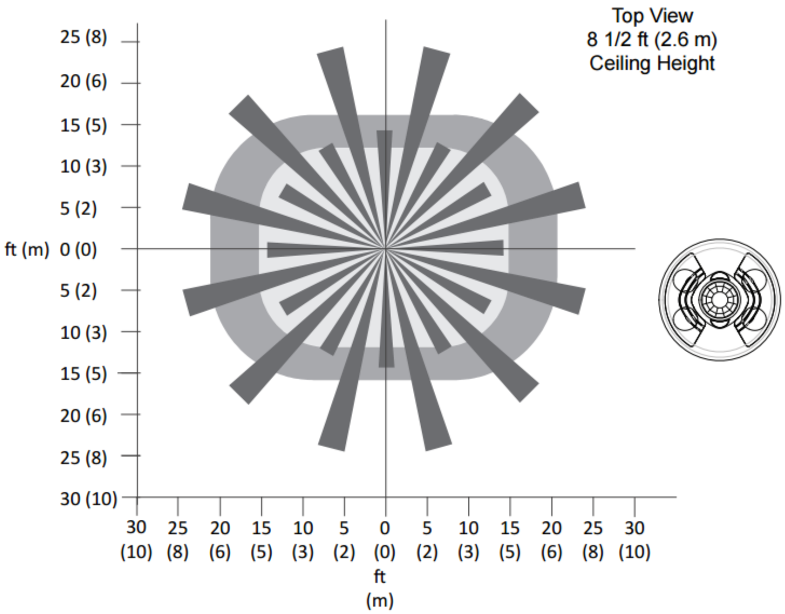


There are no battery-powered ultrasonic sensors due to the requirement that they emit a large amount of energy. The advantage of ultrasonic sensors is that they can be very sensitive to small movements. Because they use sound, there are a large number of situations that can cause false tripping.

Placement and Motion Type

With a dual technology sensor, the coverage map looks similar to the PIR coverage map with a second overlay that looks fundamentally different. Refer to the two lighter gray areas in the example below.

Placement and Motion Type Example



The light gray areas indicate where ultrasonic sensors will detect motion toward and away from the sensor.

Ultrasonic Sensor False Triggers

A problem with ultrasonic sensors is that any motion, whether from a person or a rattling vent, might trigger an erroneous response. To avoid false triggers, place sensors in such a way that nominal motion is not within the field of detection. HVAC vents moving papers or other light objects often cause false triggers. Mechanical motion in the building, such as elevator motors or fans causing ceiling tiles to rattle around slightly, can also cause the sensor to respond.

As with PIR sensors, HVAC vents pose a number of problems. Air directly blowing on the sensor could falsely trigger the sensor into believing there is motion. The same rationale applies; keep sensors away from HVAC vents.

There are other potential false triggers. Sometimes reflected sounds within the space can cause a false trigger.

Cross talk between ultrasonic sensors can also cause an erroneous response. If one sensor emits an ultrasonic impulse, the sensor next to it might hear it. The slight differences in the detected frequency can cause the sensors to believe that there is motion in the space, when in reality there is just another sensor.

Ultrasonic sensors require some component of motion to be toward or away from the sensor. This is because there will be no perceived change in frequency as there would be if the motion was toward or away from the sensor.

Sensors in Practice

Crestron sensors come in two forms: PIR and Dual Tech.

PIR sensors are appropriate for situations where there is a lot of motion, such as hallways. In these instances, the PIR elements will almost certainly cross when people are moving through the space, and the additional sensing capabilities of the ultrasonic sensors are unused.

NOTE: In areas where there are periods of slight motion when occupied, such as offices or conference rooms, use an ultrasonic sensor to avoid false vacancy scenarios.

Dual Tech sensors incorporate PIR in conjunction with ultrasonic, utilizing both sensing technologies to determine the actual state of the space. The sensors require that both the ultrasonic and PIR portions of the sensor agree that there is motion to move the system from unoccupied to occupied; however once a room is occupied, either sensor keeps the sensor in the “occupied” mode.

Common Things to Avoid

- Both technologies have failure modes surrounding proximity to HVAC ventilation. The simplest way to alleviate this problem is to keep the sensors more than 8 feet from HVAC vents. This prevents false triggering due to airflow and motion associated with the HVAC system.
- Ultrasonic sensors should be spaced more than 12 feet apart to reduce the risk of cross talk.

Best Practices by Room Type

ROOM	SENSOR TYPE
Conference Room	Dual Tech
Classroom	Dual Tech
Open Office	Dual Tech
Private Office	Dual Tech
Employee Lounge	PIR
Restroom	Dual Tech
Hallway	PIR

Useful Commands for Wired Sensors

The following commands are useful for wired sensors.

SLEV   Sets sensitivity level for ultrasonic sensor or PIR sensor.

Format: SLEV -[*sensor*] [*state*] [*level*]

sensor   - U (Ultrasonic) or P (PIR)
state   - O (Occupancy) or V (Vacancy)
level   - 1-3 (Sensitivity level)
brackets are not used

Example:

`SLEV -U V 2`
Sets ultrasonic vacancy state to level 2 sensitivity
`SLEV -P O 1`
Sets PIR occupancy state to level 1 sensitivity

SENS   Enable, disable, or show current state of sensor technologies

Format: SENS -[*sensor*] [*state*]

Sensor   - US1 (Ultrasonic sensor side A)
    - US2 (Ultrasonic sensor side B)
    - PIR (Passive Infrared Sensor)
    - MIC (Microphone)
State   - ON/OFF

Example:

`SENS -US2 OFF`
Disables Ultrasonic sensor side B.
`SENS -PIR ON`
Enables Passive Infrared Sensor.
`SENS`
Prints all status of all sensors as shown below:

US-1 enabled
US-2 enabled
PIR enabled
Mic enabled

STAT

Displays current sensitivity levels, timeout value, and detection parameters for all sensors