

- 2.5 Conduct exploratory investigations and analysis of operational parameters required for each of the control technologies (occupancy sensors, photosensors, dimming electronic ballasts) in common commercial and industrial applications, such as private and open offices and warehouses.**

Exploratory Analysis of Operational Parameters of Controls

A convenient way of analyzing control devices is to consider a device as a system of inputs and outputs. Inputs to control devices are usually sensors and commissioning set points, and the outputs are control signals that govern the operation of the controlled equipment. Once the inputs and outputs are identified, then the operation of the control device is described by how the inputs affect the outputs. The input/output relationships can either be logical relationships, continuous functional relationships, or a combination of the two. This type of analysis is effective for both small, local control systems such as an occupancy sensor in a room, and for large, distributed control systems where the outputs of devices such as occupancy and photosensors are used as inputs to higher-level building automation control systems. In fact, communication protocols for building automation systems, such as BACnet and LonWorks, are specified in terms of inputs and outputs. This report focuses on occupancy sensors, describing them in terms of inputs and outputs.

The information for this report was gathered from the publications cited as well as those listed in the bibliographies, and from manufacturers' web sites, conference seminars, product briefs and interviews with manufacturers.

Occupancy sensors

Available sensor inputs:

- Passive infrared (PIR)
- Ultrasonic
- Acoustic

Other inputs:

- Sensitivity adjustments (for PIR and ultrasonic)
- Time delay

Outputs:

- On/off power relay
- Bi-level switching on/off power
- Low voltage logic signal (to be used as an input for another controller)

Input sensing technologies

Three sensing technologies are used in occupancy sensors for commercial and industrial lighting applications: PIR, ultrasonic, and acoustic. Products are available

that use either PIR or ultrasonic, or a combination of ultrasonic or acoustic with PIR sensing. The latter are referred to as “dual technology” products.

Passive Infrared

PIR sensors respond to movement of infrared sources, such as human bodies in motion. A patterned IR transmitting lens is placed in front of a pyroelectric detector that is sensitive to the infrared blackbody radiation emitted by objects at a temperature near and around human body temperature. The patterned lens, typically of Fresnel design, focuses radiation from adjacent wedge-shaped areas of the room onto the detector. As an IR radiating object moves in and out of each segment of coverage, the signal strength received by the detector changes, signaling the detection of movement. Newer designs use a dual-element pyroelectric detector with the elements connected in series with opposite polarity. Changes in the room temperature then do not affect detection, because for static objects, both elements receive the same signal and cancel one another due to the opposite polarities of their electrical connections. The coverage area and sensitivity of a PIR sensor is greatly affected by the type of patterned lens used. Different lens designs are suited for different applications. An overall wide field of view combined with many narrow field of view segments is used for room occupancy sensors, while fewer, larger segments with an overall narrower field of view are used for corridors to maximize to length of the coverage area.

Advantages

Passive detection does not emit any potentially harmful or interfering signals. It offers the possibility of consuming very little energy to operate (potential for battery operation).

Limitations

Historically, PIR sensors have had trouble detecting small hand movements. The size of movement for reliable detection depends on the number and size of each wedge-shaped field of view segment that is focused onto the detector. The smaller the segments, the smaller the differential signal strength as an object moves. This places a limitation on how small the segments can get for a detector of a particular sensitivity. PIR sensors must have an unblocked line of sight to detect motion. Room partitions and furniture can prevent PIR sensors from detecting motion. PIR sensors are most sensitive to movement perpendicular to the direction of the sensor, as this type of movement cuts across the wedge-shaped segments. Sensitivity is lowest for objects moving directly towards and away from the sensor.

Ultrasonic sensors

Ultrasonic occupancy sensors are active devices that must emit ultrasonic sound energy at a frequency typically in the range from 25 to 40 kHz, at sound pressure levels in excess of 90 dB (0.63 Pa). Motion is detected by sensing the Doppler shift in the frequency of reflected sound waves when reflected off moving objects.

Advantages

Ultrasonic sensors cover the whole volume of the space. A direct line of sight is not required for motion detection, and motion can be detected around partitions such as inside office cubicles and lavatory stalls. Ultrasonic sensors are more sensitive to small movements than PIR sensors.

Limitations

Emission of relatively high levels of ultrasonic sound energy raises health concerns for long-term exposure, even though most sensor companies claim that their products emit less energy than the safe exposure limits set by organizations such as OSHA and the World Health Organization (WHO). Ultrasonic devices require up to 0.5 watts to generate the ultrasonic signal, so battery operation is not practical. They are also sensitive to air movement as well as body movement; therefore, HVAC system operation can cause false triggering.

Acoustic sensors

Acoustic sensors are passive devices that respond to sound pressure levels in a space; i.e., a microphone. In commercial and industrial products, these sensors are not used for primary detecting, but rather are used in combination with PIR sensors to reduce the occurrence of false off-triggers. That is, a PIR occupancy detector equipped with an acoustic sensor will only switch off the lights after a period of time during which both the PIR sensor and the acoustic sensor do not indicate occupancy.

Advantages

Simple passive device.

Limitations

Since ambient noise levels in buildings vary greatly, and acoustic sounds can travel quite far, acoustic sensors cannot differentiate sounds generated inside a space from sounds generated elsewhere. Also, occupancy does not necessarily generate sound which would lead to annoying false off-triggers in a quiet space. These facts limit the application of this technology to a secondary role in occupancy detection.

Other inputs of occupancy sensors

To help reduce the occurrence of false triggers, occupancy sensors usually have sensitivity adjustments to fine-tune operation for specific room conditions. Recent designs are incorporating more sophisticated logic for automatically adjusting sensitivity. The incorporation of microprocessors in the devices makes these new features possible at competitive prices. Sensitivity adjustments can be triggered by at least three different inputs: ambient signal strength, time of day, and on/off state of the output.

Ambient signal strength: Having sensors automatically compensate for ambient signal strength helps the device distinguish between background “noise” and the more erratic signals generated by occupant movement. Instead of having one sensitivity setting that is a compromise between adequate sensitivity for detection and background

“noise” rejection, certain sensors can dynamically adjust the signal level that causes a trigger. For example, the steady signal caused by HVAC air movement would cause the device to set a higher trigger threshold to avoid a false trigger. In the absence of a steady signal, when the HVAC system cycles off, the trigger threshold would lower, thereby increasing the likelihood of detecting occupancy.

Time of day: Sensors with microprocessors are also incorporating real-time clocks that provide a time-of-day and calendar-day input to the device. This information can be used to alter the sensitivity or trigger level of the sensor. Real-time clocks and sophisticated logic are now being combined in a form of artificial intelligence through which the sensor “learns” the daily and weekly routines of motion in the space and uses this information to dynamically adjust sensitivity and/or trigger levels.

On/off state of the output: A simpler kind of logic added to occupancy sensors permits different trigger levels to be assigned under different conditions. For example, a false trigger that turns off the lights when the room is occupied is a worse mistake than keeping the light on a few minutes longer when the room is unoccupied. Therefore, when the lights are on, a lower trigger level might be used to insure that the smallest of movements will keep the light on. On the other hand, when the lights are off, the trigger level might be set higher so that only a large movement, like someone entering the room, will trigger the lights to turn on.

Variable time delays for turning off the lights are another method used to avoid false off signals. Under one scenario, if the occupancy sensor erroneously switches the lights off while the room is occupied, the occupant will immediately make a large movement to switch the lights back on. The sensor could be programmed so that if a large signal is detected immediately after switching off the lights, the following time delay for switching off the lights for a second time might be extended. Similarly, the sensitivity could be increased, or the trigger level lowered to avoid future false off conditions.

The extent to which these different types of logic are used and how successfully they are implemented undoubtedly varies for different manufacturers. The above information was distilled from the claims manufacturers make in promoting their products and was not further verified. Nevertheless, the claims demonstrate that occupancy sensor technology for lighting products continues to be refined and developed.

Occupancy Sensor Outputs

The output from an occupancy sensor is a two-state binary signal: occupied or unoccupied. Such a signal can be directly connected to a power relay to switch lights on and off. Occupancy sensors for local control most often incorporate a power-switching relay right into the device, while others provide a logic-level signal that is connected to some other lighting controller.

While the signals from occupancy sensors are two-state, the output does not necessarily have to completely switch the light on and off. In many applications where a certain low level of illumination is always required, occupancy sensors are used for bi-level switching of the lighting. For example, occupancy sensors are used in warehouses to switch on the lights over individual aisles to provide high visibility for tasks such as reading labels, while the unoccupied part of the warehouse can remain at lower illumination levels.

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