

COSINE DEVELOPMENTS

Reg. No. IT 1637/97

LEADERS IN LIGHTING TECHNOLOGY

Occupancy Sensors Selection and Application

“The concept of occupancy sensing and its burgeoning economic substance has been spawned by inherent human indifference to green issues.”

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1. Introduction

Occupancy sensors are devices that reduce energy consumption by only activating lighting if people are present. They use a variety of techniques or combination of detection mechanisms, such as infrared, acoustic, microwave or ultrasound to sense human presence. Their use is now commonplace in developed nations but there are a number of factors will cause their rapid proliferation into the South African market:

- Rapid electricity demand and/or poor planning have resulted in marginal excess generating capacity. This will continue to be a problem until new power stations have been built.
- Increased electricity tariffs necessary to fund new power stations and force consumption awareness.
- Green issues due to global warming will dominate generations to come.

The primary role of occupancy sensors is to save money. This point is of primary consideration because the occupancy sensor must pay for itself through the savings in electricity. There is no point in installing occupancy sensors merely “go green” as the manufacture of the sensors produces a carbon footprint in itself.

An occupancy sensor consists of a motion detector - to sense human presence, a switch – to turn the lights on and a timer – to keep the lights on after movement has been sensed. Size, shape and positioning can include:

- Ceiling mount (for multi-lamp control)
- External luminaire mount (for individual lamp control)
- Internal luminaire mount (for individual lamp control behind lens)
- Wall switch mount (replaces wall switch)

A complete sensor unit usually consists of a motion detector, a photocell, a timer and a switching relay. Three user adjustable controls are usually provided: sensitivity, photocell lux level and time delay.

The sensitivity control adjusts the detection range. If this control is set too low then the probability of detecting human presence will be reduced, causing annoyance. Conversely, if the sensitivity setting is too high then the probability of false triggering is increased and could result in the lights being switched on without human presence.

The photocell can be set to provide a degree of daylight harvesting. This control ensures that the lights are not switched on if there is sufficient natural light present. If this control is set too high then the lights will be switched on regardless of natural illumination. If it is set too low then the lights will only be switched on if it is extremely dark.

The timer is used keeps the lights on between detection triggering events. If this setting is too low then the lights will extinguish frequently causing premature lamp failure and annoyance. If this setting is too high then the lights may remain on for an extended period after room evacuation.

The switching relay switched the lights on and off. It is important to ensure that the lighting load does not exceed the relay rating otherwise it could weld closed causing the lights to stay on permanently.

Units are available in wall-mounted switch configuration for use in offices or other small areas and in ceiling and wall-mounted configurations for large, open areas. There are also sensors specifically designed for luminaires.

You will need to carefully consider the time delays needed for the area, and the range, sensitivity, type, and mounting position of the sensor. For example, motion detectors may not be the right choice if occupants of the space sit very quietly at desks: people in such situations have been known to complain that they must deliberately move from time to time to prevent the sensor from shutting off the lights. Heat sensors, on the other hand, must be placed so that no obstruction blocks their sensing field.

The more hours the lights are off and the more watts controlled by the sensor, the greater the energy savings. Savings estimates of 20% to 40% are often cited, and even greater savings are possible when areas are infrequently occupied.

2. Room suitability

Savings will vary depending on the area size, type of lighting, and occupancy pattern. Manufacturers claim that in some applications, savings can approach 75%. The Californian Energy Commission estimates that typical savings range from 35-45%.

However, savings can be achieved without the use of sensors. If the occupancy pattern in an area is regular and predictable, a more effective choice is a timer system to turn lights and other equipment on and off at predetermined times. In addition, installation of sensors may not provide a payback if extensive rewiring is required. In this case, more effective conservation may come from lighting retrofits or other conservation measures.

Generally, the most effective areas for sensors are areas that are not frequently used, areas with irregular use patterns, or areas where lights are inadvertently left on. The lights are more likely to be left on overnight in individual offices, conference rooms, copier rooms, bathrooms, and storage areas. To identify other potential areas for sensors, start where lights are often on, but where there is no continuous or permanent user presence.

Lighting controls work only when they are appropriate and unobtrusive. Occupants have disabled or defeated lighting controls when they interfered with their daily routine, and there are specific areas such as hallways or stairs that should not be controlled by sensors.

The table below shows possible percentage reductions in electricity consumption after the installation of occupancy sensors:

| Area Type | Percent (%) Reduction |
|------------------------|-----------------------|
| Locker room | 65 |
| Large work room/office | 55 |
| Rest room | 50 |
| File room | 45 |
| Small work room | 40 |
| Corridors | 25 |
| Small offices | 22 |

2.1. *Trial installation*

Consider a trial installation to learn more about actual occupancy sensor performance in a given space before full installation. Note that most occupancy sensors include an LED to indicate that the sensor is detecting occupancy/motion.

The trial installation will also give the client a feel for the capabilities of the sensors. This is vital because a successful installation requires the client to understand the functionality of the occupancy sensors and the concept.

Occupancy sensors are "application-sensitive" devices, meaning that most problems in the field are the result of misapplication.

3. Important considerations

The occupancy sensors are only required because people forget to turn the lights off, however, people never forget to turn the lights on neither should the occupancy sensor. Their installation should be seamless and undetectable otherwise intense frustration inevitably results. Sensors should rather be set to leave the lights on for a little longer than to repeatedly plunge an occupied room into darkness. Frustration usually always results in the by-pass switch being thrown leaving the lights on permanently and thereby completely defeating the occupancy sensor's *raison d'être*. Consider a high profile presentation in a boardroom when all of a sudden the lights extinguish due to lack of movement sensing. Such occurrences do little to inspire confidence or prestige. It is important to consider detection capability, cost, switching capability, time delay and security to ensure an optimum installation.

3.1. *Detection capability*

It is usually preferable to suffer false detection than not to detect human presence. It should be borne in mind that inhabitants are not interested in presenting themselves for best detection by walking across infrared sensors or waving their arms at ultrasonic units. The occupancy sensor under consideration must demonstrate its detection sensitivity before installation. It is important to remember that detection sensitivity is an important cost driver in occupancy sensor manufacture – cheaper units usually have a poor detection capability. An occupancy sensor that does not detect human presence becomes incredibly frustrating and self-defeating. Generally, multi-pyro PIR sensors have more sensitivity and more uniform polar response than single unit devices.



Device sensitivity/accuracy and capability for multiple adjustments are the two most important characteristics to look for in a sensor. Selection should be a function of the type of activity in the sensing area. Distinct types of motion that occupancy sensors typically key on are: desktop-type motion such as page turning or mouse and keyboard motion, torso motion such as reaching for objects, and whole body-type motion, such as walking. Depending on type and sensitivity setting, sensors can also respond to false signals, such as air movements from HVAC vents, or motion on the desktop due to HVAC flows, or the movement of warm air in front of a sunny window.

3.2. Cost of purchase and installation

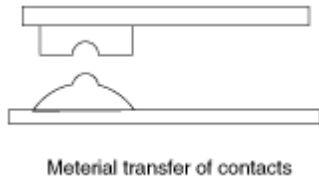
The whole reason for installing occupancy sensors is to save money. The savings in electricity must pay for the occupancy sensor installation. It is therefore vital to observe the following guidelines:

- Switch the highest possible luminaires from each sensor.
- Choose the sensor with the highest detection sensitivity.
- Select a sensor with the lowest price that has the above attributes.
- Select a supplier with local support and installation support.

Section Calculation of savings⁷ details the method to calculate savings. The **COSINE DEVELOPMENTS** Java cell phone program can be used to estimate savings on-site.

3.3. Switching capability

The maximum load switching capability of the occupancy sensor must be observed. It is important to understand that the load rating of most occupancy sensors is derived from the resistive current of its relay. The resistive current rating does not equate to a lighting current load because the lighting load has a surge component. This surge may cause material transfer across its



Material transfer of contacts

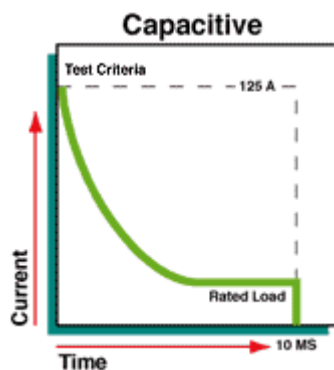
contacts as shown. If the surge currents are too high for the contact ratings then welding may occur rendering the contacts permanently closed. In this case the lights stay permanently ON and the occupancy function is disabled. The material transfer across the contacts is cumulative *i.e.*, its damaging

effect may not initially be noticed: failure may only occur later. This problem often occurs with low-grade sensors.

Three surge phenomenon are associated with lighting:

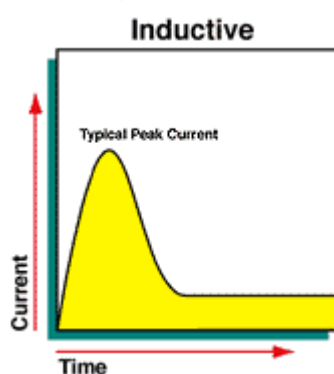
3.3.1. Capacitive load surge

The surge current typical of a capacitive load is usually presented by electronic ballasts and fluorescent electromagnetic ballasts fitted with power factor correcting capacitors. In these cases, the in-rush surge current can momentarily exceed 100 Amps. The surge is greatest when the switching instant coincides with the mains voltage peak. The capacitive surge current is of very short duration and so does not trip the main breaker, but its effect can be damaging to the relay within the occupancy sensor.



3.3.2. Inductive load surge

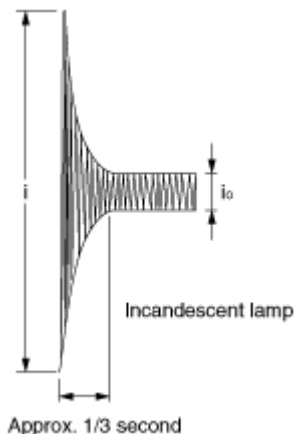
The surge current waveform typical of an inductive load is shown in the figure.



An electromagnetic ballast without any power factor correction would cause such a waveform. Although of a lower peak value than the capacitive load, it is nevertheless higher than the steady state current value. The maximum surge current coincides when switching occurs during a mains voltage zero.

3.3.3. Incandescent load surge

The momentary current surge of incandescent lamps is due to the fact that their cold resistance is usually about 10% of their hot (running) resistance. The figure shows a typical surge current when an incandescent lamp is first switched ON. These graphs merely demonstrate that the resistive load rating quoted by many occupancy sensor manufacturers can be very misleading when compared with transient lighting loads.



If maximum resistive load figures are quoted then it is prudent de-rate the value by 10 times to predict the maximum real-world lighting load.

3.4. Time delay

All sensors have a timer to keep the lights ON between movement detection events. This prevents the lights from turning ON and OFF unnecessarily. The timer re-starts every time movement is detected and so with general office activity the lights should stay ON continuously. There may be periods, however, when no activity is detected but people are present: they may be reading (or asleep). It is therefore important that the occupancy sensor has a long delay timer to cover periods of inactivity (no detection).

Unnecessary light switchings have the following effects:

- Reduced lamp life: Halogen lamps and instant start fluorescent lamps age quicker with repeated starts.
- User resistance: Occupants will become annoyed.

It is therefore important to set the occupancy sensors on their maximum delay time: It is preferable to keep the lights ON for a few minutes after the occupants have left than to switch the OFF whilst they are present.

3.5. Security

Consider both security and comfort issues in any occupancy system design. It is disconcerting for a worker to be surrounded in darkness if he is alone in the building.

4. Sensor types

Sensor topologies utilise various means of detecting human presence.

Available types of sensor technologies are infrared or passive infrared (PIR), ultrasonic or ultra sound (US), microwave, and audio.

4.1. *Passive Infrared (PIR)*

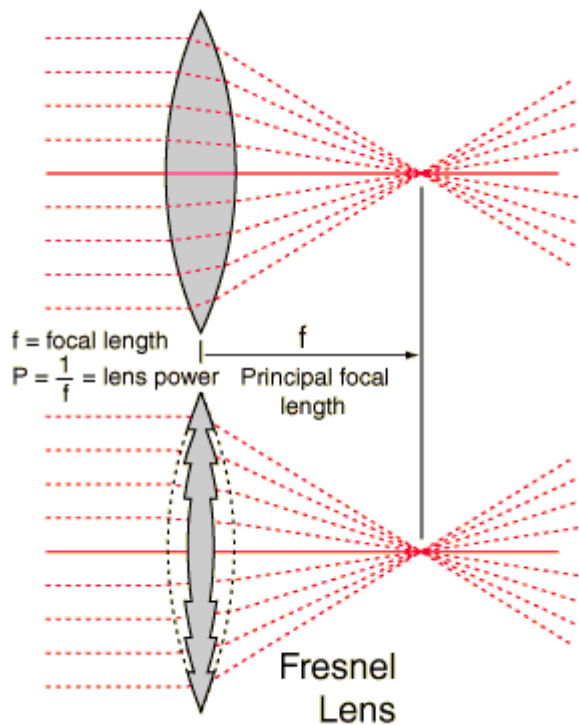
A PIR sensor detects heat changes. Therefore, any heat source may cause the PIR sensor to trigger. Heat sources include people, animals, air conditioning wind currents, wind currents, windows (during the day) and incandescent lamps. A passive infrared sensor detects heat only within its "line of sight." It cannot detect the heat through walls or other obstacles. They detect motion within a fan shaped pattern. The sensor's ability to detect motion also depends on the distance between the sensor and the location of the motion. At short distances, within 3 metres, the sensor can detect very small motions such as hand movement. As the distance between movement and the sensor increases, larger motions are required to trigger the sensor. When a person is 10 to 15 metres away from the sensor, it will only detect large movements such as a person walking around.

PIR sensors are very resistant to false triggering. Although some PIR sensors have an operating range of up to 15 metres in specific directions under ideal conditions, they are most reliable only within a 5-metre range because:

- The blind spots between their wedge-shaped sensory patterns get wider with distance—the sensor is most sensitive to movement laterally across the field of view.
- They are passive—they don't send out any signal—and depend on the intensity of the heat from the moving part of the subject, which drops with the square of the distance.

The PIR uses a Fresnel lens to divide the room into segments, the principle of which is explained below:

The Fresnel Lens



Faced with the need to construct a large lens for a lighthouse of appropriate focal length, but unable to support the large weight of a double convex lens of that size, French physicist Augustin Fresnel (1788-1827) reasoned that it was the surface curvature which gave the focusing power. He reproduced the surface curvature of the thick lens in sections, maintaining the same focal length with a fraction of the weight.

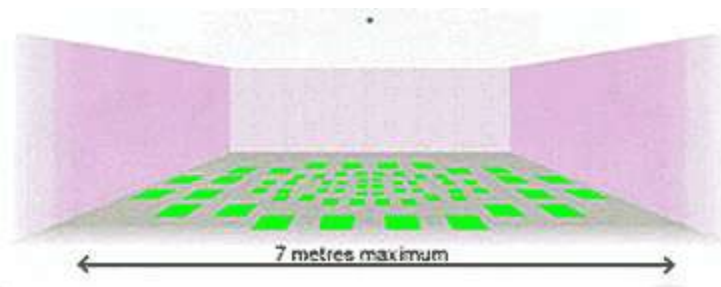
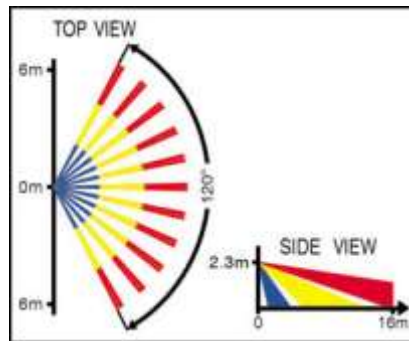
Besides the glass Fresnel lenses you see in old lighthouses, large Fresnel lenses made from molded plastic are used for occupancy sensors and alarm sensors. The optical quality is not sufficient for good imaging because of the scattering you get at the junctions between the curved segments, resulting in rings of light in the image plane.

The image below shows a typical Fresnel lens on an occupancy sensor:

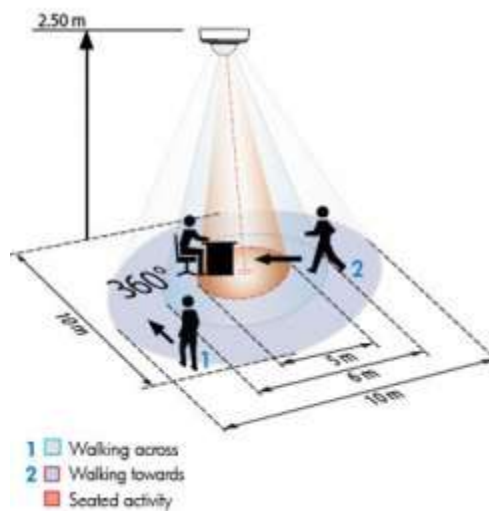


The number of segments on the Fresnel lens determines how many segments the room is divided into. Therefore, the more segments the better and the greater the size of the Fresnel lens the better. The sensor is triggered if heat detected in any segment alters. This could be due to a person walking across segments or due to a curtain

blowing in front of a window. The figures below show typical detection segments and their partitioning of a room:



The picture below shows typical sensitivities to various movements:



Issues that might complicate their application include low levels of motion by occupants, obstacles blocking the sensor's view, and sensors mounted on sources of vibration or within 6-8 feet of air diffusers

4.1.1. Strengths

- Very resistant to false triggering.
- Passive detection: No energy is radiated into the room.

- Mature technology: PIR sensors have been used for many years in alarm systems.

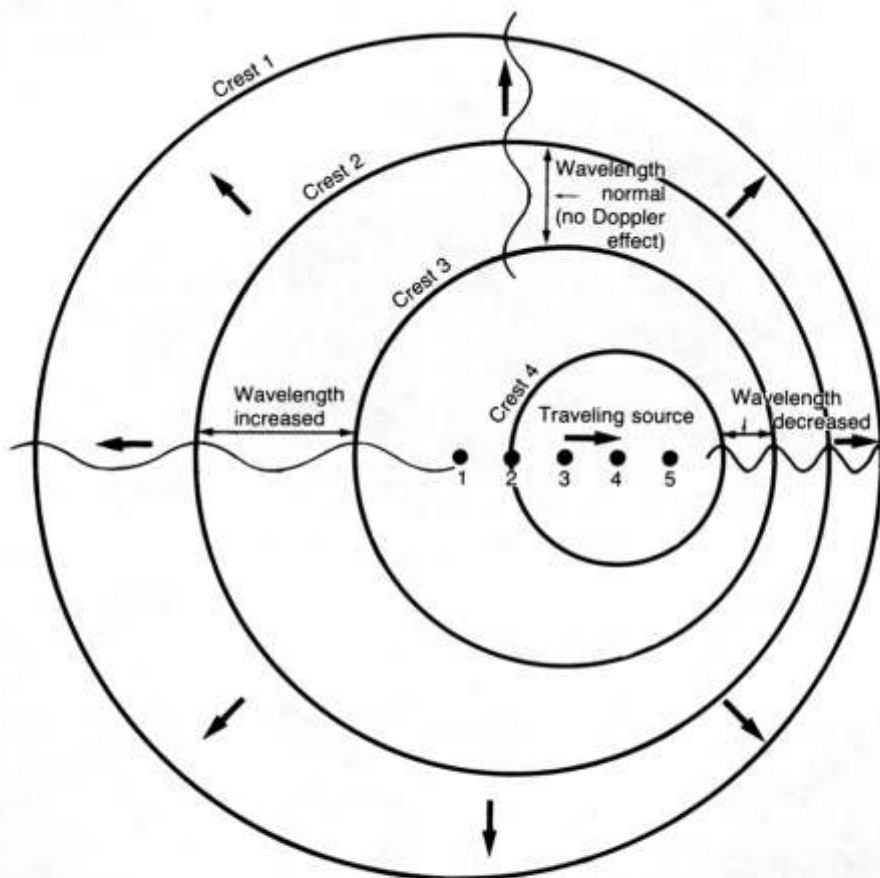
4.1.2. Weaknesses

- Detection depends on Fresnel surface area: small sensors can have limited detection range.
- Sensitive to wind currents: False triggering can occur if mounted too close to air conditioners or windy corridors.
- Detection depends on number of Fresnel segments: Blind spots are inevitable due to room compartmentalisation.
- Line of sight: Movement must be visible to the sensor. It cannot sense through room partitions.
- Radial insensitivity: It is more sensitive to movement across its path than towards or away.

4.2. *Ultrasonic (US) Sensors*

These are active: They emit a high-frequency sound (above 20 kHz, so that it's beyond human and animal audibility ranges) and listen for the reflected sound—a moving object will introduce a frequency change. This effect is known as the Doppler Effect and is explained below:

DOPPLER EFFECT DIAGRAM

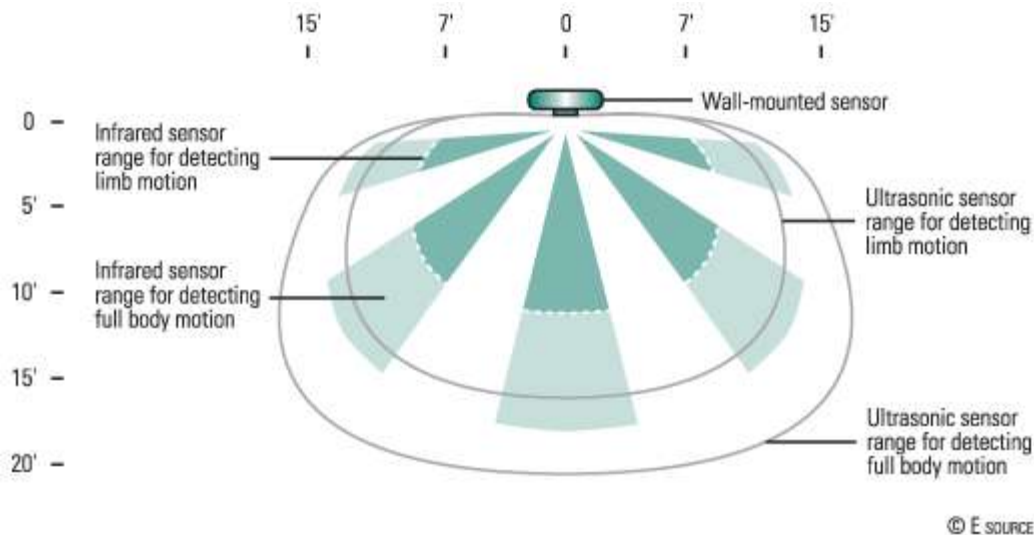


A source of sound waves (in air) traveling from points 1 to 5 appears to radiate shorter wavelengths in the direction it is approaching (to the right) and longer wavelengths in the opposite direction (to the left). This is the Doppler effect.

In this example, the source is traveling at half the velocity of the sound wave so the wavelength to the right is half the normal wavelength, while to the left it is three-halves (or 50 percent more than) the normal wavelength. Perpendicular to the travel direction of the source (up or down on the diagram), the wavelength is normal (no Doppler effect).

From the above it is clear that occupancy sensors using the Doppler Effect are more sensitive to movement towards or away from the sensor than across it.

Because they emit a signal instead of passively receiving, US sensors are able to cover larger areas than PIR sensors (see figure below) and are noticeably more sensitive. Ultrasonic sensors, however, are more prone to false triggering. Air motion—caused by a person running by a doorway or a ventilator cycling on or off—can trigger a poorly located or maladjusted sensor. US sensors can also be triggered by curtains, shades, or blinds that move with air currents.



Ultrasonic sensors can detect motion at any point within the contour lines. Infrared sensors see only in the wedge-shaped zones, and they don't generally see as far as ultrasonic units. The ranges are representative; actual sensors may be more or less sensitive.

Ultrasonic sensors are not as limited to line-of-sight motion detection as infrared sensors. They have limited sensitivity around obstacles such as walls or cubicles. These sensors are best specified for open offices, restrooms, or store rooms where the many obstacles make infrared sensors useless.

Ultrasonic sensors are also more sensitive to line-of-sight movement than infrared sensors. Small hand motions can be detected up to 20 feet away compared to about 10 feet for the infrared sensor.

Ultrasonic devices are generally more expensive than infrared devices, but they provide greater coverage for larger spaces. These units are more sensitive to motion than infrared units but are also more prone to false triggering. False triggering occurs when the sensor detects non-occupant movements: This might include air movement from the ventilation system or even a breeze through an open window. Proper calibration can address this problem.

Ultrasonic occupancy sensors, with its distinctive advantages and limitations, can be more appropriate for some applications than PIR sensors, and vice versa. Neither technology is superior except in the context of an individual application need related to cost, sensitivity, line of sight, field of view, etc.

Issues that might complicate their application include: ceilings higher than 14 feet; high levels of vibration or air flow, which can cause nuisance switching; and open spaces that require selective coverage, such as control of individual warehouse aisles.

4.2.1. Strengths

- No blind spots: A continuous bubble of energy envelops the room.
- Not limited to line of sight: US sensors can see around some furnishings.
- High sensitivity: US sensors are usually more sensitive to PIR sensors.

4.2.2. Weaknesses

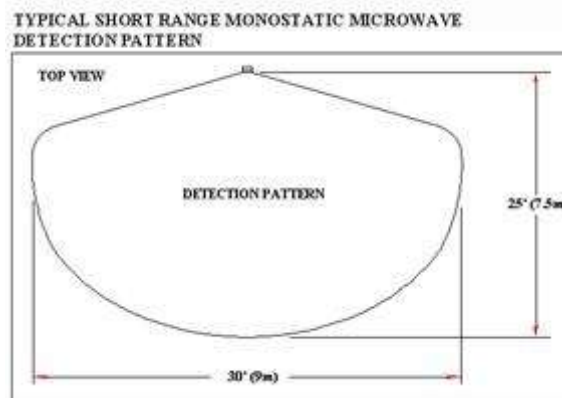
- Cost: They are usually more expensive than PIR's
- False triggering: US sensors are more prone to false triggering than PIR sensors.

4.3. Microwave Sensors

Microwave sensors use ultrahigh-frequency radio waves, also known as “microwaves” and the principle of the Doppler Effect to detect motion. Their operation is similar to a police radar gun. The sensor sends out radio waves that bounce off nearby surfaces and return to the sensor. Motion in the area changes the speed of the waves returning to the sensor. The sensor detects the change and interprets it as occupancy.

High frequency radio waves can penetrate certain materials, therefore, they can be installed behind a luminaries' plastic or glass lens or in a watertight non-metallic box or watertight luminaire for wet location applications.

The microwave sensor fills the room with a “bubble” of energy as shown in the diagram below. There are no blind spots. The microwave energy can also reflect off surfaces and thereby sense around corners to a degree.



4.3.1. Strengths

- No blind spots: the room is not segmented as with PIR's.
- Can sense through room dividers, windows and soft furnishings: it is ideal for toilets and high shelf stock rooms.
- Not affected by wind currents: Both PIR's and US sensors are susceptible to false triggering from wind.
- Is not triggered by curtain movements: US sensors are prone to false triggering by moving curtains.
- Does not have to be visible: It can be mounted behind ceiling boards and does therefore not impact on room aesthetics.

4.3.2. Weaknesses

- Cost: they are usually expensive.
- Triggering from adjacent rooms: this can lead to false triggering, particularly from adjacent corridors.
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4.4. *Acoustic and Hybrid sensors*

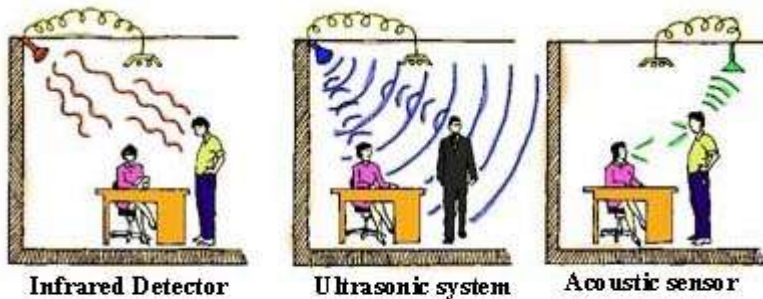
4.4.1. Acoustic Sensors

Acoustic sensors detect noise made by people and mechanical noise related to human activity, such as keyboard tapping, paper shuffling, and photocopying. Unfortunately, these sensors also respond to sounds that have nothing to do with occupancy, such as slammed doors and street noise, and they require relatively high sound levels (higher than a typical quiet office) to activate. Few if any sensors use only acoustic technology, but some sensors combine PIR with acoustics to increase reliability

4.4.2. Hybrid sensors

Hybrid, or dual-technology, sensors incorporate features of different sensor types in one unit. The most common combination of sensor types is that of PIR and US sensors, which take advantage of the PIR units' resistance to false triggering and the sensitivity of ultrasonic sensors.

Dual-technology sensors activate the lights only when both technologies detect the presence of occupants. This setup virtually eliminates the possibility of false-on problems, and requiring either technology to hold the lights on significantly reduces the possibility of false-off problems. The picture below shows the different methods of detecting occupancy:



Occupancy Sensor Technologies

4.5. **Advanced sensors**

Sensors are always improving. For example, some new infrared sensors are equipped with double-eye sets to minimize blind spots. Ultrasonic "boosters" enable a single wall-mounted sensor to cover very large or oddly shaped rooms without additional wiring. When connected to a heavy-duty relay, a single boosted US sensor can effectively cover several thousand square feet, needing only hand or arm motion to trigger it. Other switches combine occupancy sensors with dimmers to take advantage of the energy-saving potential of both technologies. Line-voltage sensors have recently become available that make it practical to install occupancy sensors on individual fixtures in applications such as high-bay facilities, and they are reliable, cost about half as much as earlier sensors, and install in half the time.

New "smart" sensors use microprocessors to provide automatic sensitivity or time adjustment and incorporate sophisticated analysis of the detected signals to improve operational reliability. Unlike a traditional sensor that uses a preset time-delay, after which a sensor that hasn't detected any presence will shut off, a smart sensor can "learn" the changing activity levels and habits of building occupants and adapt the time delay to improve performance.

5. **Installation criteria**

Key considerations to consider in any installation are:

Consider the mode of occupation, i.e. predicted traffic and direction of movement. Small movements are always difficult to detect and in such

instances, the time setting should be set on maximum. Do not install sensors in spaces where there are extremely low levels of occupant motion.

Wall or ceiling mount? Wall-mounted sensors are OK for smaller rooms such as offices, restrooms, and equipment rooms (such as printer or copier rooms) where people are only likely to be present for a short time after they walk by the sensor. In an open-plan office or, where the lighting load is higher, mount the sensor in the ceiling.

Install sensors carefully. Sensors are easy to spot, and people might be tempted to adjust, steal, or vandalize them, or they may just try to fool the sensors into perceiving a human presence when a space is unoccupied. To ensure continued energy savings, position the sensors carefully and train building occupants on their purpose.

Involve building personnel in planning for the sensors. Understand local occupancy patterns. Occupancy sensors generate the greatest savings in spaces where occupancy is unpredictable and/or intermittent.

Train maintenance personnel and office occupants to keep sensors operational, rather than disconnecting them as problems occur.

Determine the range of detection coverage. Position sensors so they only "see" the area intended to be observed—the most common cause of false triggering is incorrect positioning. Line of sight must be maintained between the sensor and the occupant except in the case of an enclosed space with hard surfaces covered by a microwave sensor. Be sure to view sensor specifications to determine the amount of coverage that will be provided to the space by the sensor; this will aid with choosing the number of sensors required to cover an area properly and where to place them.

Position sensors away from air ducts and windows. Do not install sensors within 6-8 feet of HVAC outlets or heating blowers.

Calibrate the sensor. The sensor will be provided with manufacturer-default settings for sensitivity to magnitude of motion and time delay before switching the lights off. The default time delay may be from 30 seconds to 15 minutes. Be sure to calibrate the sensor to specific conditions in the space for best performance.

Avoid conditions that may result in false triggering. Conditions to generally avoid include using a microwave sensor for restricted-coverage areas and high-bay and outdoor applications; setting the microwave sensor to maximum sensitivity so that it picks up small non-human movements in the space; and setting the sensor so that it turns off too quickly or cannot see the occupant, such as bathrooms/stalls. Avoid placing a microwave sensor where it can pick up vibrations, and placing a PIR sensor where it is exposed to direct sunlight that can trigger it. If a PIR sensor has a line of sight into an adjacent hallway, resulting in false triggers, then simply put a masking label

on the section of the lens that can "see" into the hallway to restrict its coverage.

Consider the direction of motion. Microwave sensors are most sensitive to occupants moving towards and away from the sensor, while PIR sensors are most sensitive to lateral motion.

Check the load limits for the sensor selected. Ensure that the load handled by the sensor is within the minimum and maximum limits specified by the manufacturer.

Ballast compatibility. Check with the manufacturer to determine if there is a limitation in compatibility with any other lighting equipment, such as electronic ballasts.

Lamp life. Determine switching's effect on lamp life. Frequent switching can shorten lamp life, particularly if the lamps are instant start lamps (including ES CFL's). However, also calculate into the total impact of occupancy sensors the effect of reduced operating hours.

Ultrasonic sensors. Do not Use ultrasonic sensors in spaces with heavy air flow.

Parallel connection. Do not parallel connect too many sensors making it difficult to fault find and commission.

Wall light switch. Connect the sensors before the wall light switch so that the sensors remain permanently energised. In this way the occupants can still turn the lights ON and OFF as desired and the occupancy sensor does not have to "wake up" when the lights are turned ON.

6. Commissioning

The success of the commissioning will, to a large degree, determine the effectiveness of the installation. The following procedure should be followed to commission the system:

- Set photocell sensitivity to maximum.
- Set the time and sensitivity to minimum.
- Walk throughout the installation whilst increasing the sensitivity setting.
- Only after having determined that the sensitivity settings are optimum; set the time controls to maximum.
- Adjust the photocell setting to $\frac{3}{4}$ of maximum.
- Educate occupants about the new devices and what to expect.
-

6.1. Light level adjustment

The **COSINE DEVELOPMENTS** occupancy sensors have a day-lighting control capability. The daylight control is a “HOLD-OFF” type. This means that the sensor stops the load from turning ON if the ambient light level is greater than the day-lighting set point adjustment. If the load is already ON, the sensor will not turn the load OFF due to high ambient light levels. The photocell sensing is only enabled after time-out.

The photocell provides a daylight harvesting function i.e., it inhibits energising the lighting during periods of high natural lighting. However, this facility is inaccurate and should not be relied upon in areas with statutory required minimum lighting levels.

6.2. Sensitivity adjustment

The sensitivity adjustment adjusts the minimum detection range.

6.3. Time delay adjustment

The occupancy sensors have re-triggerable timers. This means that once movement is detected a timer begins and is reset every time movement is detected.

7. Calculation of savings

The projected savings after the installation of occupancy sensors is predicted by considering room usage, lamp power and cost of electricity. Follow the steps below to compute predicted savings:

STEP 1 – Cost of sensor

This should be the installed cost, which includes the cost of the sensor plus the installation charge (*CS*).

STEP 2 Number of lamps

Survey the room and wiring arrangement (back to the light switch). Identify the maximum number of lamps that can be switched by the sensor (*NL*).

Step 3 – Wattage

Identify the wattage of each lamp. Dissipation of the ballast can be ignored if electronic ballasts are used (*W*).

STEP 4 – Daily burning hours

Ask the user for the normal daily burning hours of the relevant circuit and compute the monthly burning hours (*MH*).

STEP 5 – Electricity tariff

Determine the cost of electricity for the installation from the chart below. Note: these prices are increasing in the near future (*ET*).

| Tariff region | Tariff rate (rands per kWhr) |
|----------------------|------------------------------|
| Commercial low load | |
| Commercial high load | |
| Residential | R0.58 |
| Commercial | R0.59 |
| | |

STEP 6 – Compute the monthly cost in electricity (MC)

Use the equation below to compute actual monthly cost in rands:

$$NL \times W \times MH \times ET \div 1000 = MC$$

STEP 7 – Identify room type

The table below shows typical vacancy percentages for various room types. Select the appropriate room type (*RT*).

| Room type | Percentage saving |
|------------------|-------------------|
| Private offices | 45% |
| Conference rooms | 60% |
| Rest rooms | 70% |
| Corridors | 65% |
| Storage areas | 65% |
| Meeting rooms | 90% |
| Hotel rooms | 40% |

STEP 8 – Predicted monthly savings

The predicted monthly savings (in rands) will be:

$$\text{Monthly Savings (MS)} = RT \times MC \div 100$$

STEP 9 Compute payback period

The payback period can be simply computed by dividing the installation cost by the savings:

$$\text{Payback period (months)} = CS \div MS$$