Notes on Occupancy Sensors (Longer Version)

Preface. This document might be a bit nerdy and not entirely useful for lay readers. I’m an electrical engineer that designs occupancy sensors for a living. This is the first time I’ve been asked to write about occupancy sensors for non-technical readers.

Basics. Occupancy sensors turn off lights when no one is around to benefit from the light, so they are energy-saving devices. If electricity were free, there would be no market for occupancy sensors. They used to be called motion detectors because they detected movement of human bodies: lights went off when motion was no longer detected in front of the sensor. The slang expression today among those who make and sell them is “occ sensor”. I will use that abbreviated term going forward.

Ultrasonic Sensors. In the early days, all occ sensors used ultrasonic detection methods. Today a minority of sensors use this detection technology. Like flying bats, ultrasonic occ sensors generate a loud sound field at a frequency above the range of human hearing. The ultrasound sound bounces off objects and people in the room and is reflected back to the occ sensor. A microcomputer inside the occ sensor compares the radiated ultrasound with the reflected ultrasound and discerns motion.

The sensing range of ultrasonic occ sensors is tens of feet. They work best in closed spaces like bedrooms or offices. For instance, you would never use an ultrasonic sensor in a warehouse because the space is too large to fill with ultrasound.

The most useful feature of ultrasonic occ sensors is that they can see around partitions and file cabinets. The most irritating feature of ultrasonic occ sensors is that they frequently false trigger on moving air from HVAC vents. Moving air currents look like moving people to ultrasonic sensors.

PIR Sensors. The majority of occ sensors sold today are termed PIR sensors, meaning Passive InfraRed sensors. They sense motion by seeing heat emitted by warm objects like people as they pass through their field of view. PIR sensors use a curved plastic Fresnel lens on their front surface.

If you examine a PIR sensor you’ll see that its curved Fresnel lens has a number of grooved fish eye patterns stamped into it. These fish eyes are called lenslets. A moving person in the room must pass through the field of view of at least two of the lenslets in the Fresnel lens in order for the sensor to see motion.

The sensing range of PIR occ sensors is generally less than 20 feet, but special ones can be constructed that see moving people at distances greater than 60 feet. Generally speaking, PIR occ sensors cannot see a moving person if there is an intervening object between the sensor and the person.

Wall-mounted PIR sensors don’t work well in rooms that have office cubicles defined by carpeted walls. Reason: partition walls are opaque to the IR energy given off by people. PIR sensors can be used in bathrooms off public buildings provided that the sensor’s time-out setting is longer than the time a person spends in a toilet stall. In other words, the “hang time” of wall-mounted PIR bathroom sensors must be set to at least 5 minutes else the light will go off while a person is in a stall.

PIR sensors are generally immune to the moving air from HVAC vents. However, they can be overloaded and rendered useless by nearby space heaters or direct sunlight.

Dual Technology Sensors. Premium grade occ sensors (known as dual technology sensors) utilize both ultrasonic and PIR sensing methods. The sensor’s onboard microprocessor compares the ultrasonic and PIR signals and gleans motion with greater immunity to ambient noise compared to one of these sensing methods used alone. In some dual technology sensors, the microprocessor learns which of the sensing technologies is most accurate by recording
when the user manually overrides it. These sensors are said to be **adaptive**. They self-teach the best detection strategy.

Premium grade sensors are generally sold only at electrical distributors.

**Front Panel Manual Override Switches.** The majority of occ sensors sold today are designed to mount in a wall junction box in lieu of the ordinary toggle switch that the original builder installed. All wall mount occ sensors contain pushbuttons on their front surface that mimic the behavior of the toggle switch they replaced. You might ask “**Why? Offering front panel override buttons that mimic the switches they replaced invites energy wasting habits**”. Answer: a significant percentage of wall-mounted occ sensors work poorly. Room occupants need some way to turn lights on and off when the motion sensing feature of the device doesn’t work, or stops working after some period of useful operation.

The above criticism of occ sensors needs clarification. If a sensor is properly chosen and located based on the room’s configuration, it will work 100% of the time and over a period measured in years. However, many occ sensors are not suitable for the room they serve or their location in the room is not optimum. These bad actors have created a less-than-stellar reputation for lighting controls.

**Ceiling Mounted Sensors.** For manufacturers of occ sensors, the wall-mounted versions constitute the “sweet spot” in the lighting market. Demand for these devices grows every year and annual sales volume exceeds $500M. Hence most of the engineering improvements in occ sensors over the past decade have been directed toward the wall-mount market. They now fit in the crowded spaces in junction boxes, even if there are wire nuts in the boxes. Older sensors would not fit into crowded j-boxes. Additionally, modern occ sensors are flush with the front surface of the wall plate. Older versions stuck out prominently from the faceplate and were easily damaged by passersby.

However, every occ sensor manufacturer offers ceiling-mounted sensors that address some of the shortcomings of wall mounted sensors. These sensors require specialized accessories and wiring methods, and thus they are not sold by DIY stores like Home Depot and Lowes.

Ceiling mounted sensors have these virtues:

- They can see 360° on the floor under them compared to the fan-shaped viewing beams of wall mounted versions.
- They are more sensitive and can see over office and bathroom partitions.
- Several sensors can be daisy-chained to cover large areas. If any sensor on a daisy chained string sees motion, the lights controlled by the daisy chain will turn on.
- They can control lighting loads of greater total wattage than wall-mounted versions.

Typical load ratings for ceiling sensors are 20 amps compared to 10-15 amp ratings for wall-mounted devices.

Wattage ratings for 120VAC sensors follow this rule: 5 amps equals 600 watts, 15 amps equals 1800 watts, and 20 amps equals 2400 watts. How long an occ sensor will last when driving high wattage loads is very dependent on design. Poorly-designed sensors may not make it to the end of their warranty period before the switching relay in the sensor fails due to load.

Ceiling mounted sensors have these shortcomings:

- They’re substantially more expensive than wall-mounted sensors and must be purchased outside the traditional DIY outlets.
- They are occasionally too sensitive and trigger on motion in hallways outside the room they serve.
- They require the use of a companion device known as a power pack whose role is to switch the light fixtures on and off.
- Installing ceiling sensors requires getting above the ceiling and employing wiring skills not generally possessed by DIY folks.
• Most of the ceiling sensors on the market do not offer a wall mounted manual override switch. If the attached light fixture turns off prematurely, there is no switch for the user to slap to turn the light back on.

Although there are exceptions, ceiling-mounted occ sensors generally target the high dollar niche in the lighting market where a trained electrician installs and provisions the sensors. Ceiling mounted sensors and their required accessories are sold by electrical distributors that cater to electricians. These distributors are not friendly (either by price or bedside manner) to DIY’ers.

Hardware sold by electrical distributors has two prices: a “rack price” that is 2x to 3x what they actually sell for and a negotiated “trade” price that can be very low if the sensor is purchased in a large bid package involving dozens or hundreds of sensors. A layperson who stops at an electrical distributor for a few occ sensors will be offered the rack price, not the bid package price.

I once worked for a large electrical hardware conglomerate that purchased ceiling mounted sensors from China for $13 in quantity. Our rack price at distributor walk-up counters was $80 but these sensors were often sold for $40 in large bid packages. They required the use of power packs that sold for similar prices.

Vacancy Sensors. All sensor manufacturers sell a software variant of their wall mount occ sensors that is called a vacancy sensor by the electrical trade. Hardware-wise, a vacancy sensor looks, smells, and installs just like a wall mounted occupancy sensor. (For all practical purposes, they are occ sensors.)

However, a vacancy sensor will not turn on lights when it sees motion. The room occupant must slap the front of the sensor with his hand to initiate light. The vacancy sensor will use its motion sensing capability to determine when the light turns off.

This is a summary of the difference between an occ sensor and a vacancy sensor:

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Turn on Strategy</th>
<th>Turn Off Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occ sensor</td>
<td>when motion is detected</td>
<td>5-15 minutes after motion ceases</td>
</tr>
<tr>
<td>Vacancy sensor</td>
<td>when the occupant hits the switch</td>
<td>5-15 minutes after motion ceases</td>
</tr>
</tbody>
</table>

Vacancy sensors are intended for pass-through rooms or short hallways where light is not always needed as the occupant moves quickly toward his final destination in the home or building. If used in a short pass-through hallway, a standard occ sensor would give 5-15 minutes of unnecessary light even though the occupant never intended to remain in that room for more than a few seconds.

Although things might have changed in the past two years, vacancy sensors were generally not sold by DIY stores.

Safety Considerations. Needless to say, the voltages and currents present in wall junction boxes and light fixtures can be lethal. No one without appropriate training should enter junction boxes or light fixtures, and never without turning off AC power first.

Not all commercial occ sensors offer the same level of user safety. Some low-cost occ sensors are sold without being subjected pre-sale to testing by a recognized national safety laboratory such as Underwriters Laboratories or Intertek/ETL. In many jurisdictions, local building inspectors forbid the use of occ sensors that do not carry approval by some recognized safety laboratory. Insurance companies encourage and support building inspectors in their preference for certified safe products.

What can happen to an occ sensor that sees field use without possessing the necessary safety approvals? They can present serious shock hazards to users or possibly start a fire. Everyone has seen wall-mounted occ sensors that have been vandalized by children. The most frequently vandalized part of the occ sensor is the curved Fresnel
lens on the front. When this lens is removed by a vandal, it’s important that no hazardous voltage be exposed to users. In sensors lacking safety certifications, this protection is often missing.

Uncertified occ sensors frequently cannot drive high wattage lighting loads or they fail early in their life when they drive heavy loads. Hopefully, a sensor that fails under a heavy load will turn into an open circuit and simply cease to control the attached lighting load, thereby notifying the building owner that a failure has occurred. However, in some instances a failing occ sensor can overheat and start a fire in the junction box. Safety laboratories test all devices to make certain that their plastic housings do not support or sustain a flame.

Summary: always buy sensors and light fixtures that bear an Underwriters Lab or Intertek/ETL safety certification mark. The dollars saved by buying uncertified sensors do not justify the risk they carry. Additionally, uncertified sensors may harbor design flaws that will make them annoying to install and use.

**Multi-Way Wall Mount Occ Sensors.** If your targeted application has light fixtures controlled by wall switches installed at 2 or more locations in the hallway or room, you have multi-way wall switches. The most popular is a 2-way configuration with switches at either end of a hallway. Also popular are three switch configurations that employ two 2-way switches and one 3-way switch.

You can use wall mounted occ sensors in applications involving multi-way switches, but these occ sensors are specialized devices generally sold only at electrical distributors at high price. Beginners should stick with replacing only simple 1-way SPST wall switches with wall mounted occ sensors.

*Jim Olson*  
*Indianapolis, IN*  
*September 1, 2014*