

A **Passive InfraRed sensor (PIR sensor)** is an [electronic device](#) which measures [infrared](#) light radiating from objects in its field of view. Apparent motion is detected when an infrared source with one [temperature](#), such as a [human](#), passes in front of an infrared source with another temperature, such as a [wall](#).

All objects emit what is known as [black body radiation](#). This energy is invisible to the human [eye](#) but can be detected by [electronic devices](#) designed for such a purpose. The term 'passive' in this instance means the PIR does not emit energy of any type but merely accepts incoming infrared radiation.



## Design

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Infrared radiation enters through the front of the sensor, known as the *sensor face*. At the core of a PIR is a [solid state sensor](#) or set of sensors, made from approximately 1/4 [inches](#) square of natural or artificial [pyroelectric materials](#), usually in the form of a [thin film](#), out of [gallium nitride](#) (GaN), [caesium nitrate](#) (CsNO<sub>3</sub>), [polyvinyl fluorides](#), derivatives of [phenylpyrazine](#), and [cobalt phthalocyanine](#). (See [pyroelectric crystals](#).) [Lithium tantalate](#) (LiTaO<sub>3</sub>) is a [crystal](#) exhibiting both [piezoelectric](#) and pyroelectric properties.

The sensor is often manufactured as part of an [integrated circuit](#) and may consist of one (1), two (2) or four (4) 'pixels' of equal areas of the pyroelectric material. Pairs of the sensor pixels may be wired as opposite inputs to a [differential amplifier](#). In such a configuration, the PIR measurements cancel each other so that the average temperature of the field of view is removed from the electrical signal; an increase of IR energy across the entire sensor is self-cancelling and will not trigger the device. This allows the device to resist false indications of change in the event of being exposed to flashes of light or field-wide illumination. (Continuous bright light could still saturate the sensor materials and render the sensor unable to register further information.) At the same time, this differential arrangement minimizes [common-mode interference](#); this allows the device to resist triggering due to nearby electric fields. However, a differential pair of sensors cannot measure temperature in that configuration and therefore this configuration is specialized for *motion detectors*.

## PIR-based motion detector

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Cylindrical facet lens in front of PIR sensor. Each facet (rectangle) is a Fresnel lens

In a PIR-based motion detector, the PIR sensor is typically mounted on a [printed circuit board](#) which also contains the necessary electronics required to interpret the signals from the chip. The complete circuit is contained in a housing which is then mounted in a location where the sensor can view the area to be monitored. Infrared energy is able to reach the sensor through the window because the plastic used is transparent to infrared radiation (but only [translucent](#) to visible light). This plastic sheet prevents the introduction of dust and insects which could obscure the sensor's field of view.

A few mechanisms have been used to focus the distant infrared energy onto the sensor surface. The window may have [Fresnel lenses](#) molded into it. Alternatively, sometimes PIR sensors are used with plastic segmented [parabolic mirrors](#) to focus the infrared energy; when mirrors are used, the plastic window cover has no Fresnel lenses molded into it. A filtering window (or lens) may be used to limit the wavelengths to 8-14 micrometers which is most sensitive to human infrared radiation (9.4 micrometers being the strongest).

The PIR device can be thought of as a kind of infrared 'camera' which remembers the amount of infrared energy focused on its surface. Once power is applied to the PIR the electronics in the PIR shortly settle into a quiescent state and energize a small [relay](#). This relay controls a set of [electrical contacts](#) which are usually connected to the detection input of an alarm control panel. If the amount of infrared energy focused on the sensor changes within a configured time period, the device will switch the state of the alarm output relay. The alarm output relay is typically a "normally closed (NC)" relay, also known as a "Form B" relay.

A person entering the monitored area is detected when the infrared energy emitted from the intruder's body is focused by a Fresnel lens or a mirror segment and overlaps a section on the chip which had previously been looking at some much cooler part of the protected area. That portion of the chip is now much warmer than when the intruder wasn't there. As the intruder

moves, so does the hot spot on the surface of the chip. This moving hot spot causes the electronics connected to the chip to de-energize the relay, operating its contacts, thereby activating the detection input on the alarm control panel. Conversely, if an intruder were to try to defeat a PIR perhaps by holding some sort of thermal shield between himself and the PIR, a corresponding 'cold' spot moving across the face of the chip will also cause the relay to de-energize — unless the thermal shield has the same temperature as the objects behind it.

Manufacturers recommend careful placement of their products to prevent [false alarms](#). They suggest mounting the PIRs in such a way that the PIR cannot 'see' out of a window. Although the [wavelength](#) of infrared radiation to which the chips are sensitive does not penetrate glass very well, a strong infrared source (a vehicle headlight, sunlight reflecting from a vehicle window) can overload the chip with enough infrared energy to fool the electronics and cause a false (non-intruder caused) alarm. A person moving on the other side of the glass however would not be 'seen' by the PIR.

They also recommended that the PIR not be placed in such a position that an [HVAC](#) vent would blow hot or cold air onto the surface of the plastic which covers the housing's window. Although air has very low [emissivity](#) (emits very small amounts of infrared energy), the air blowing on the plastic window cover could change the plastic's temperature enough to, once again, fool the electronics.

PIRs come in many configurations for a wide variety of applications. The most common used in [home security systems](#) has numerous Fresnel lenses or mirror segments and has an effective range of about thirty feet. Some larger PIRs are made with single segment mirrors and can sense changes in infrared energy over one hundred feet away from the PIR. There are also PIRs designed with reversible orientation mirrors which allow either broad coverage (110° wide) or very narrow 'curtain' coverage.

PIRs can have more than one internal sensing element so that, with the appropriate electronics and Fresnel lens, it can detect direction. Left to right, right to left, up or down and provide an appropriate output signal.

## • In Short

### Passive InfraRed ( PIR )

The most frequent use of the **PIR** sensor is as an '**area**' sensor. Whether it is to detect 'someone moving in the front yard', or 'someone moving in the bathroom', or 'someone moving through a doorway', or even 'someone opened the beer cooler', it is all technically the same sensor and logic.

There is a simple electronic device which is sensitive to '**heat**', or rather the infrared light that is emitted by warm or hot objects (like humans).

In its simplest form, it looks like an old metal transistor with a black plastic 'window' on the top.



The 'logic' of the PIR sensor is that it must detect 'significant change' of the normal level of heat within the 'field' of its view. The circuits that control it must be able to determine what 'normal' is, and then close a switch when the normal field changes, as when a human walks in front of it.

It must also be able to 'tolerate' slow changes within the field, and remember that as the new 'normal'. This is so that gradual changes like the sunlight changes throughout the day, don't cause a false alarm. This is a standard behavior of 'PIR' type sensors. (There's a lot more electronics there than just the black window...)

### • Why does the sensor wear 'lenses' ?

You'll notice in all three pictures of PIR type sensors on this page, that they all have some sort of plastic 'lens' that covers the circuit board and the PIR sensor device.

This is a 'Fresnel' lens. It 'pinches' light that passes thru it. If you hold it to your eye, you can see that there are apparent distinct 'bars' of light as you move it across a scene. Some of these bars may be vertical, and some may be horizontally oriented.

The lenses that are made for most PIR sensors, tend to 'pinch' the light such that it is **horizontally** sensitive.

This means that the Lens/PIR will be more sensitive to motion of a warm body, horizontally 'across the field of view'.

**Please** note that this means that these sensors are most **insensitive** to warm bodies moving from a 'distance' and directly **towards** one of these common devices...!

### **What does a motion sensor say ?**

- All motion sensors send an "ON" message when they first see motion.
- Most will also send an "OFF" message when motion has not been seen for a set period of time.
- Some will continue to send "ON" messages periodically as long as motion continues.
- Others may only announce the first event, and say nothing again until the area has been quiet for a set period of time.