8. Proximity Sensing

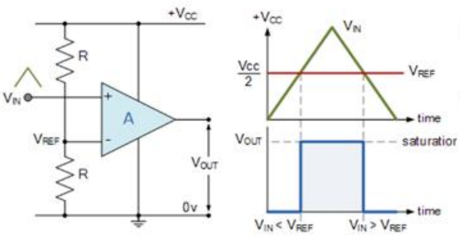
A critical distance is measured by proximity sensors. In effect, a proximity sensor is a threshold version of a position detector. A position sensor is often a linear device whose output signal represents a distance to the object from a certain reference point. A proximity sensor, however, is a somewhat simpler device which generates the output signal when a certain distance to the object becomes essential for an indication.

The three most common types of non-contact sensors in use today are the inductive proximity sensor, the capacitive proximity sensor, and the optical proximity sensor. All of these sensors are actually transducers, but they include control circuitry that allows them to be used as switches. The circuitry changes an internal switch when the transducer output reaches a certain value, and the output of the switch becomes the control systems proximity sensor.

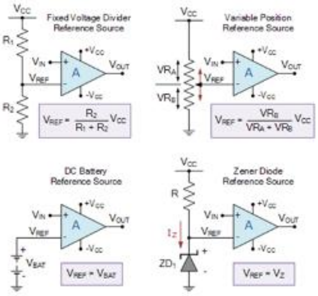
The sensor output is generally connected to a comparator opamp. The Op-amp comparator compares one analogue voltage level with another analogue voltage level, or some preset reference voltage, V_{REF} and produces an output signal based on this voltage comparison.
Voltage comparators use

- positive feedback or no feedback at all (open-loop mode) to switch its output between two saturated states,
- because in the open-loop mode the amplifiers voltage gain is basically equal to AVO.
- Then due to this high open loop gain, the output from the comparator swings either fully to its positive supply rail, +Vcc or fully to its negative supply rail, -Vcc
- on the application of varying input signal which passes some preset threshold value.

The threshold value or reference voltage can be supplied to opamp by various ways.



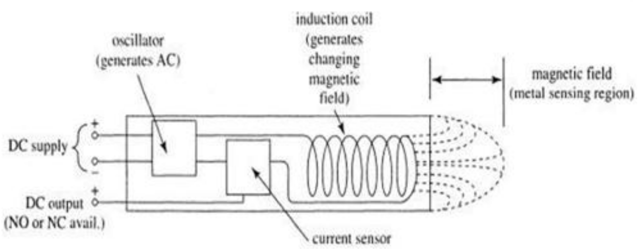
Non-inverting Comparator Circuit

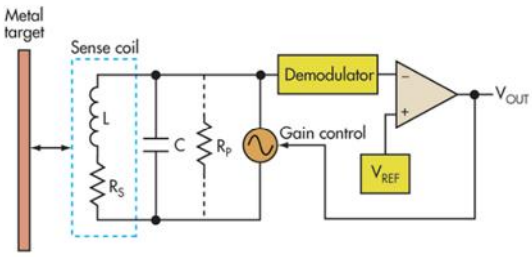


In this non-inverting configuration, the reference voltage is connected to the inverting input of the operational amplifier with the input signal connected to the non-inverting input.
the two resistors forming the potential divider network are equal and: $R_1 = R_2 = R$. This will produce a fixed reference voltage which is one half that of the supply voltage, that is $V_{cc}/2$,
When V_{IN} is greater than V_{REF}, the op-amp comparators output will saturate towards the positive supply rail, Vcc.
When V_{IN} is less than V_{REF} the op-amp comparators output will change state and saturate at the negative supply rail, 0v as shown.

Inductive Proximity Switches

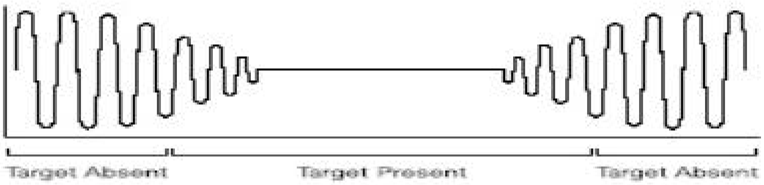
Inductive proximity sensors are used for non-contact detection of metallic objects.





Their operating principle is based on a coil and oscillator that creates an electromagnetic field in the close surroundings of the sensing surface.
The oscillator generates a sine wave of a fixed frequency. This signal is used to drive the coil. The coil in conjunction with ferrite core induces a electromagnetic field.

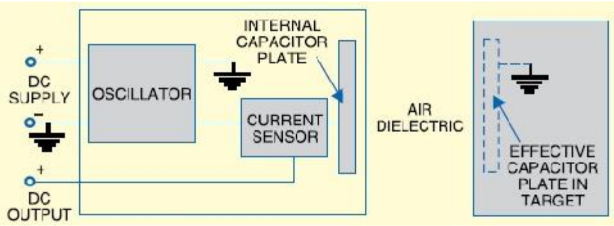
When the field lines are interrupted by a metal object, the oscillator voltage is reduced, proportional to the size and distance of the object from the coil.

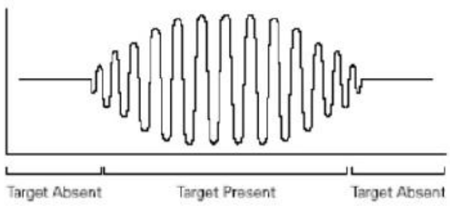


The reduction in the oscillator voltage is caused by eddy currents induced in the metal interrupting the field lines. Objects that do not conduct electricity, such as wood and plastic, cannot be detected by inductive proximity sensor

Capacitive Proximity Switches

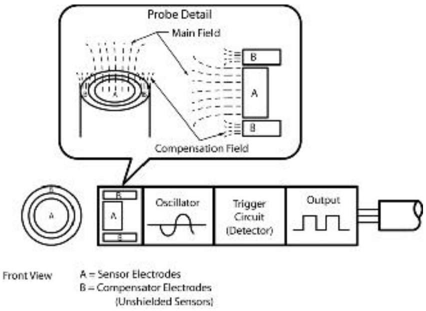
Capacitive proximity sensors sense "target" objects due to the target's ability to be electrically charged. Since even non-conductors can hold charges, this means that just about any object can be detected with this type of sensor.





Their operating principle is based on an LC oscillator circuit with capacitor part which has only one plate. The object to be detected actually forms the second plate of the capacitor. By this means, the circuit can function properly.
the current on inductor tries to charge a capacitor but the capacitors can hold a charge because, when one plate is charged positively, negative charges are attracted into the other plate, unless both plates are present and close to each other.
Only one of the required two capacitor plates is actually built into the capacitive sensor. The target being sensed acts as the other plate. If this object is near enough to the face of the capacitive sensor to be affected by the charge in the sensor's internal capacitor plate, it will respond by becoming oppositely charged near the sensor.

The sensor will then be able to move significant current into and out of its internal plate.



Another configuration of sensor utilizes two metallic electrodes or plates to create the sensing element in a capacitive proximity detector. The electrodes form a capacitor in the feedback loop of a high-frequency oscillator. The amount of capacitance is a function of the surface area of the two electrodes, the distance between the electrodes, and the dielectric constant of the material between the electrodes.
The capacitance is low with no target present, so the oscillation amplitude is small. A target approaching the face of the sensor changes the dielectric constant between the plates and raises the capacitance. The higher capacitance boosts the amplitude of the oscillations being measured by a level-detection circuit. When the amplitude of the oscillations exceeds a specific value, the level detector turns on the output of the sensor. As oscillation amplitude falls below the threshold, the level detector turns the sensor output off.

Conductive targets affect capacitive sensors as well, but in a different way. When a conductive target enters the sensor field it forms a counter electrode to the active face of the sensor. The target effectively reduces the distance between electrodes and boosts the average surface area. The net result is a jump in the capacitance value, the same as for a nonconductive target.

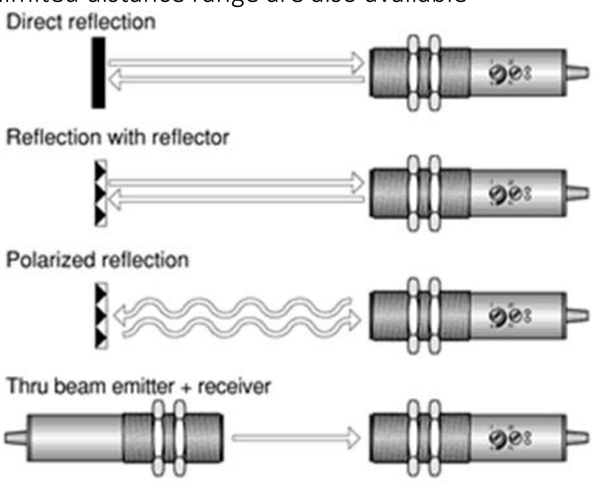
Optical Proximity Switches

Optical proximity sensors generally cost more than inductive proximity sensors, and about the same as capacitive sensors. They are widely used in automated systems because they have been available longer and because some can fit into small locations. These sensors are more commonly known as light beam sensors of the thru-beam type or of the retro reflective type.

A complete optical proximity sensor includes a light source, and a sensor that detects the light. The light source is supplied because it is usually critical that the light be "tailored" for the light sensor system. The light source generates light of a frequency that the light sensor is best able to detect, and that is not likely to be generated by other nearby sources. Infra-red light is used in most optical sensors. To make the light sensing system more foolproof, most optical proximity sensor light sources pulse the infra-red light on and off at a fixed frequency. The light sensor circuit is designed so that light that is not pulsing at this frequency is rejected.

The light sensor in the optical proximity sensor is typically a semiconductor device such as a photodiode, which generates a small current when light energy strikes it, or more commonly a phototransistor or a photo-darlington that allows current to flow if light strikes it. Early light sensors used photoconductive materials that became better conductors, and thus allowed current to pass, when light energy struck them. Sensor control circuitry is also required. The control circuitry may have to match the pulsing frequency of the transmitter with the light sensor. Control circuitry is also often used to switch the output circuit at a certain light level. Light beam sensors that output voltage or current proportional to the received light level are also available.

Through beam type sensors are usually used to signal the presence of an object that blocks light. If they have adjustable switching levels, they can be used, for example, to detect whether or not bottles are filled by the amount of light that passes through the bottle. Retroflective type light sensors have the transmitter and receiver in the same package. They detect targets that reflect light back to the sensor. Retroreflective sensors that are focused to recognize targets within only a limited distance range are also available



Direct Reflection (Diffused) - emitter and receiver are housed together and use the light reflected directly off the object for detection. In the use of these photocells, it is important to bear in mind the color and the type of surface of the object. With opaque surfaces, the sensing distance is affected by the color of the object. Light colors correspond to the maximum distances and vice versa. In the case of shiny objects, the effect of the surface is more important than the color. The sensing distance in the technical data is related to matte white paper.

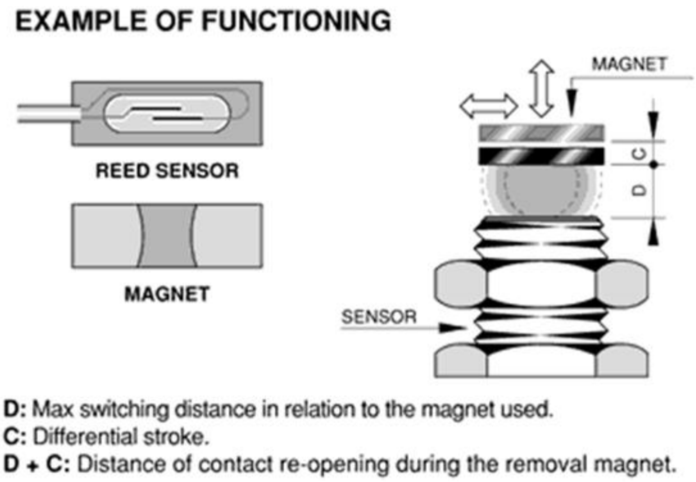
Reflection with Reflector (Retroreflective) - emitter and receiver are housed together and requires a reflector. An object is detected when it interrupts the light beam between the sensor and reflector. These photocells allow longer sensing distances, as the rays emitted are almost totally reflected towards the receiver.

Polarized Reflection with Reflector - similar to Reflection with Reflector, these photocells use an anti-reflex device. The use of such a device, which bases its functioning on a polarized band of light, offers considerable advantages and secure readings even when the object to be sensed has a very shiny surface. They are not in the technical data affected by random reflections.

Magnetic proximity switch

Magnetic proximity sensors are actuated by the presence of a permanent magnet. Their operating principle is based on the use of reed con-tacts, whose thin plates are hermetically sealed in a glass bulb with inert gas. The presences of a magnetic field makes the thin plates flex and touch each other causing an electrical contact. The plate's surface has been treated with a special material par-ticularly suitable for low current or high inductive circuits. Magnetic sensors compared to traditional mechanical switches have the following advantage:

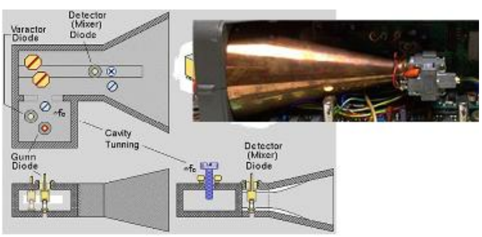
Contacts are well protected against dust, oxidization and corrosion due to the hermetic glass bulb and inert gas; contacts are activated by means of a magnetic field rather than mechanical parts
Special surface treatment of contacts assures long contact life
Maintenance free
Easy operation
Reduced size

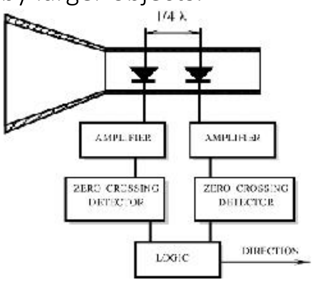


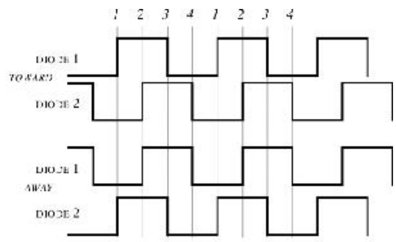
Motion detectors
Motion detectors respond only to moving objects. The applications of these sensors include security, surveillance, energy management, (electric lights control), personal safety, friendly home appliances, interactive toys,

Microwave detectors

Microwave detectors: active sensors responsive to microwave electromagnetic signals reflected from objects.
The operating principle of the microwave detector is based on radiation of electromagnetic radio-frequency (RF) waves toward a protected area
Microwaves are a form of electromagnetic radiation with wavelengths ranging from one meter to one millimeter; with frequencies between 300 MHz (100 cm) and 300 GHz (0.1 cm). The most common frequencies are 10.525 GHz and 24.125 GHz (K band).These wavelengths are long enough (λ =3 cm) to pass freely through most contaminants, such as airborne dust, and short enough for being reflected by larger objects.







The microwave part of the detector consists of a Gunn oscillator, an antenna, and a mixer diode. The Gunn oscillator is a circuit which oscillates at microwave frequencies. The produced electromagnetic waves is directed through an iris into a waveguide and focusing antenna which directs the radiation toward the object.

The smaller part of the microwave oscillations is coupled to the Schottky mixing diode and serves as a reference signal. In many cases, the transmitter and the receiver are contained in one module called a transceiver. The target reflects some waves back toward the antenna, which directs the received radiation toward the mixing diode.

The Doppler effect is the basis for the operation of microwave and ultrasonic detectors. It should be noted that the Doppler effect device is a true motion detector because it is responsive only to moving targets.

Doppler effect: The Doppler effect is the change in the frequency of a wave motion when there is relative motion between the source and the observer.

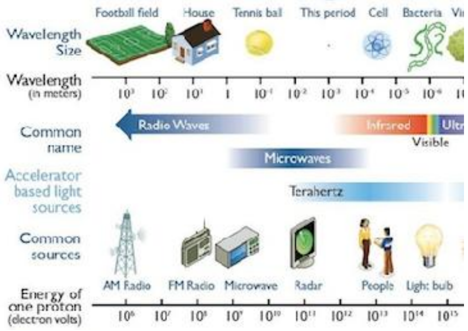
As a wave source approaches, an observer encounters waves with a higher frequency. As the wave source moves away, an observer encounters waves with a lower frequency. The apparent change in frequency is known as the Doppler Shift.The Doppler shift increases as the relative velocity between the source and the observer increases.
The Doppler effect applies to all forms of waves

Ultrasonic detectors

Ultrasonic detectors: similar to microwaves except that instead of electromagnetic radiation, ultrasonic waves are used. These detectors are based on the transmission to the object and receiving reflected acoustic waves.

Infrared motion detectors

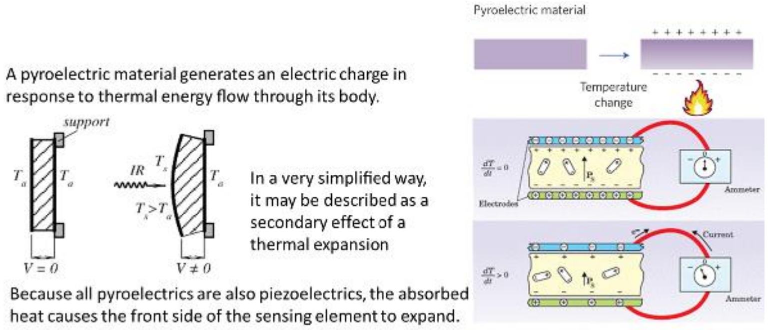
Infrared motion detectors: devices sensitive to heat waves emanated from warm or cold moving objects and operates in the optical range of thermal radiation. All matter with a temperature greater than absolute zero emits thermal radiation. When the temperature of a body is greater than absolute zero, inter-atomic collisions cause the kinetic energy of the atoms or molecules to change.



the optical range of thermal radiation is subdivided into ultraviolet radiation (UV), the spectrum of light visible for man (VIS) and infrared radiation (IR). It ranges between wavelengths of 100 nm to 1 mm. Electromagnetic waves in this range obey the laws of optics--they can be focused and refracted with lenses.

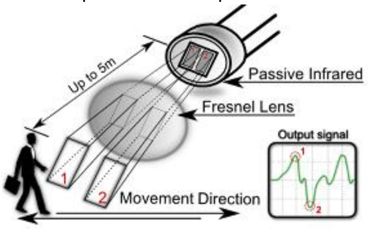
For motion detection, it is essential that the surface temperature of an object be different from that of the surrounding objects, so that a thermal contrast would exist.

PIR Motion Detectors:
A PIR is a passive infrared motion sensor. It detects infrared energy, which is in a form of a temperature that is radiated from body of humans, animals and other objects



The magnitude of infrared energy can be quantified by a pyroelectric sensor. This sensor is placed behind an infrared-transparent cover, so that it may monitor objects with varying infrared energy. Similarly to the way an electric charge is created when visible light strikes a solar cell, these sensors generate a small charge when subjected to infrared energy
The PIR sensing element must be responsive to far-infrared radiation within a spectral range from 4 to 20 µm, where most of the thermal power emanated by humans is concentrated.

A pyroelectric material generates an electric charge in response to thermal energy flow through its body. In a very simplified way, it may be described as a secondary effect of a thermal expansion. Because all pyroelectrics are also piezoelectrics, the absorbed heat causes the front side of the sensing element to expand. The resulting thermally induced stress leads to the development of a piezoelectric charge on the element electrodes.



when a human walks into the sensors detection range, the temperature in that range changes from a temperature of room objects (if used indoors), which is lower, to a temperature of a human body, which is higher and when a human walks out of the detection range the temperature changes back to the temperature of room objects. A PIR sensor detects these changes in temperature and transfers them into electrical signals