Pyroelectric Infrared Sensors & a Power Operational Amplifier

By Joseph Desposito

A passive infrared detector works much like the human eye in that it is a one-way receiver. At the heart of this type of device is something called a ceramic pyroelectric infrared sensor. The sensor consists of an infrared detecting element and a low-noise impedance-matching circuit, both contained in a metal package with an infrared transmitting window.

The sensitive element is an electrically polarized ceramic slice with infrared transmitting metallic electrodes deposited on opposite faces. The pyroelectric nature of the ceramic causes the electrodes to produce an electrical output signal in response to changes in temperature. Sensors intended for movement detection have a daylight filter that ensures that the device is insensitive to short wavelength infrared, as emitted by the sun.

Electrically, a sensor can be represented by one or two capacitors (depending on whether it is a single- or dual-element device), an n-channel FET, and a nonlinear network, connected as shown in Fig. 1. The dual-element devices have two differentially connected sensitive areas with a single impedance-converting amplifier to provide immunity from common-mode signals such as those generated by variations in ambient temperature, background radiation, and acoustic noise.

The pyroelectric ceramic material used in sensors developed by the Amperex Electronic Corp. (Smithfield, RI) is a doped lead zirconate titanate, which is optimized for infrared applications. It is insensitive to water, is rugged, and can be handled by mass production techniques similar to those used in the manufacture of conventional semiconductor devices. The material has a high Curie temperature, and can operate up to 70 degrees Fahrenheit. Furthermore, responsivity is only slightly temperature dependent.

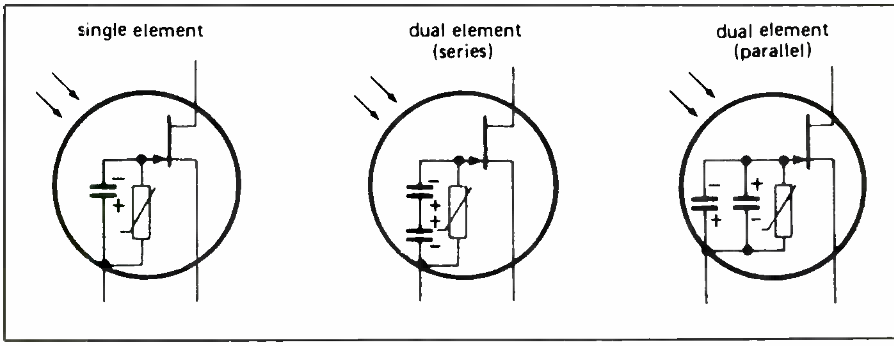

Fig. 1. An infrared sensor can be electrically represented by one or two capacitors, an n-channel FET and a non-linear network.

What is Pyroelectricity?

A pyroelectric ceramic is composed of a mass of minute crystallites, each of which behaves as a small electric dipole. Above a certain temperature, known as the Curie temperature, the crystallites have no dipole moment. Below the Curie temperature in freshly manufactured material, the electric dipoles are randomly oriented (see Fig. 2A). If the material is heated to just below the Curie temperature in an electric field, the dipoles tend to line up with the applied field (see Fig. 2B). After the material has cooled and the field has been removed, the dipoles remain in the "poled" position, giving rise to a remanent polarization of the ceramic.

The pyroelectric effect arises because of a change in polarization with temperature and may occur in several ways. For example, the individual dipoles may shorten with increasing temperature, or the total dipole moment may be reduced by increased randomness of the orientation of the dipoles due to thermal agitation. Thus, when the temperature of the material increases, the captive surface charge is reduced. This leaves a surfeit of induced charge on the electrodes. The excess charge gradually leaks away through the circuit to which the pyroelectric element is connected. This leakage effect means that a pyroelectric sensor cannot be used in a dc mode. However, it can be operated at very low frequencies down to less than 0.1 Hz.

The pyroelectric element will only produce an output signal if the infrared radiation incident on it changes. This may be achieved either by moving the object of interest into and out of the field of view,

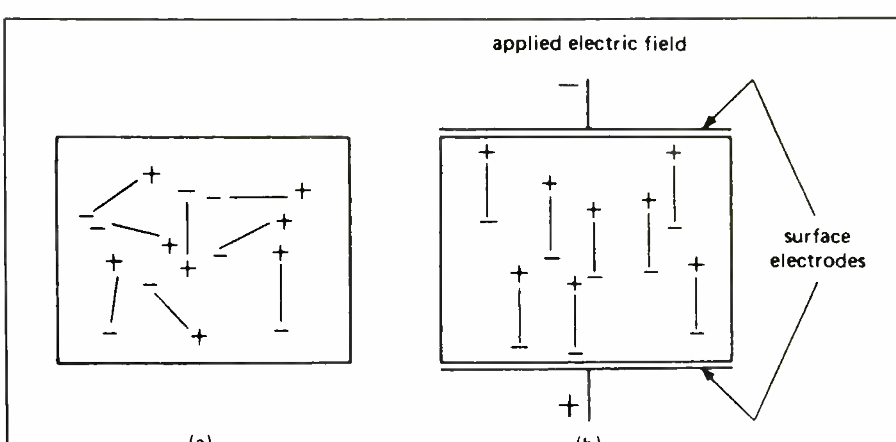

Fig. 2. A pyroelectric ceramic consists of a mass of minute crystallites, each of which behaves as a small dipole, that are randomly oriented (A) below and are aligned (B) when heated to just below the Curie temperature and an electrical field is applied.

www.americanradiohistory.com

or by interrupting the radiation incident on the sensor.

Passive IR Detection

Each person, object or animal emits infrared energy as a function of its surface temperature and size. For temperatures around ambient, the maximum radiated energy is in the region of 10 microns (20 times the wavelength of visible light). Radiation changes produced by a moving object can be detected by a pyroelectric infrared sensor.

A pyroelectric infrared sensor can be used as the basis for a passive infrared (PIR) alarm system. This type of system detects the presence of an intruder within a protected area when movement modulates the radiation incident on pyroelectric sensors that respond only to changes in radiation. An intruder will emit a steady infrared radiation. One way that radiation can be collected is by a Fresnel lens array (a Fresnel lens is a thin polyethylene sheet that is essentially equivalent to thick conventional lenses).

Discrete fields of view from each element ensure significant changes in incident radiation when an intruder passes from an unmonitored gap to a monitored zone or vice-versa. A Fresnel lens array is suitable for most general-purpose moving-sensing PIR applications. It provides high sensitivity, monitoring up to at least 12 meters with 90° angular coverage.

Figure 3 shows the block diagram of a simple passive infrared intruder alarm system. The output from the PIR sensor with its Fresnel Lens array is amplified by two bandpass amplifier stages. A window comparator with positive and negative threshold then drives a logic circuit. This performs simple signal processing and drives the output alarm relay circuit.

For detailed information and a sample device, write on your company letterhead to Amperex Electronic Corp., A North American Philips Co., George Washington Hwy., Smithfield, RI 02917.

Long-Range Detection

Eltec Instruments, Inc. (P.O. Box 9610, Daytona Beach, FL 32020-9610) manufactures the Eltec IR-EYE 862, which can detect people outdoors to a distance of 500 feet (vehicles can be detected to even greater distances).

A person or vehicle will always have a temperature contrast in respect to the background, producing a change of radiation within the field of operation of the sensor when passing through it. For the IR-EYE 862, this temperature contrast can be as little as 1 degree centigrade or less (either positive or negative) for a person at a nominal distance of 150m to trigger an alarm. A precision mirror focuses the radiation onto a parallel opposed dual pyroelectric detector. This will produce a defined signal from a moving object while canceling common mode signal received simultaneously by both sensing elements.

Two-stage optical filtering restricts the radiation to the so-called atmospheric window (8-14 microns). Here the effects of normal constituents of the atmosphere (particularly humidity) least affect the transmission of infrared radiation. This double optical filtering blocks all unwanted radiation from sunlight and headlights, which otherwise may produce false alarms.

Sophisticated signal processing within the eye is used to discriminate even very weak signals caused by a moving target from unwanted signals caused by wind, clouds and precipitation.

Eltec has produced a brochure that describes the principles of operation, functioning, detectability considerations, and installation of non-imaging passive infrared telescopes. Copies of the brochure are available from Eltec Instruments, Inc. at the address given above.

Power Op Amp

A versatile and forgiving power operational amplifier is now available from the

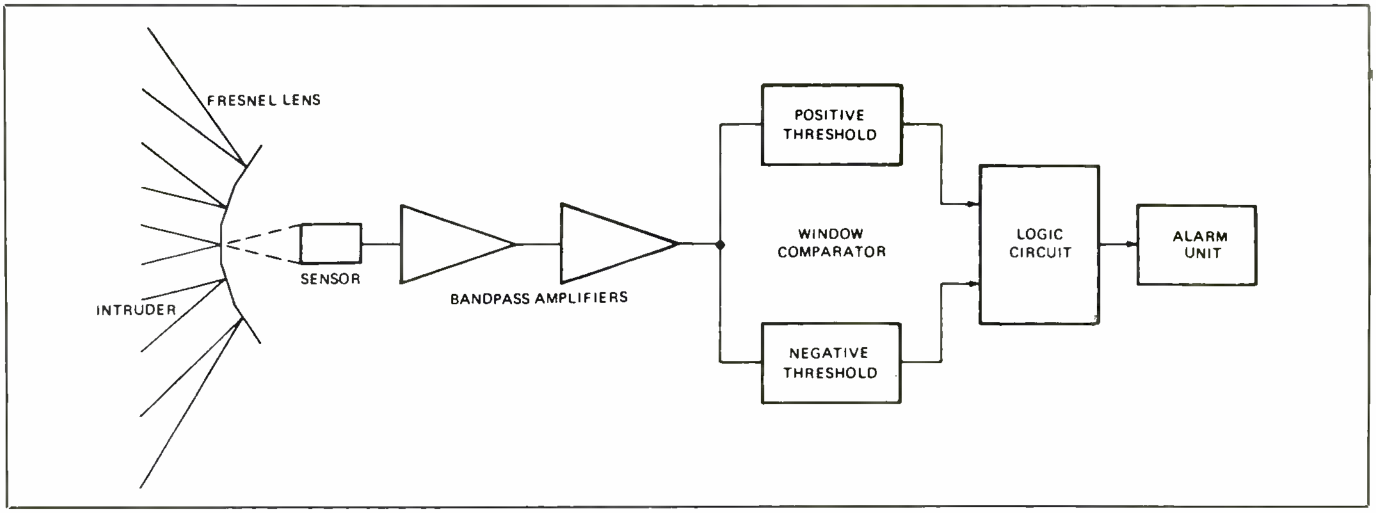

Fig. 3. Block diagram of a simple passive infrared intruder alarm system.

www.americanradiohistory.com

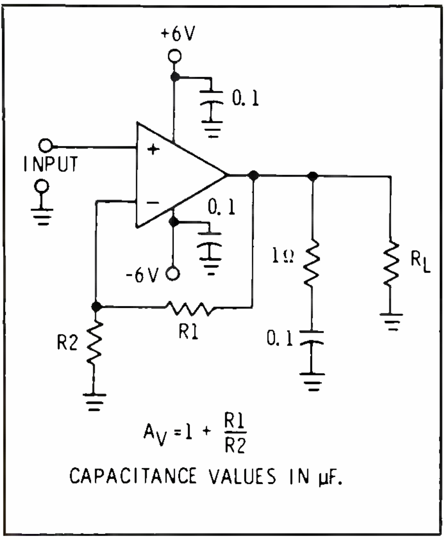

Fig. 4. Typical application of the ULN-3751Z operational amplifier as a non-inverting power amplifier.

Semiconductor Group of Sprague Electric Co. (41 Hampden Rd., P.O. Box 9102, Mansfield, MA 02048). Operating with power supply voltages of ±3 volts to ±13 volts or 6 volts to 26 volts, the ULN-3751Z delivers peak output current levels to ±3.5 amperes. This integrated circuit is ideal for use in servo systems, robotics, audio and deflection amplifiers, and software programmable voltage or current regulators.

The amplifier requires no external components for loop compensation and maintains a stable, oscillation free operation for all values of gain in the inverting or non-inverting mode, and under all specified load conditions. Low input current and voltage offsets of 10 nA (typical) and ±10 mV (maximum) make the device simple and convenient to use. A self-resetting shutdown circuit powers down the amplifier at a junction temperature of 160 degrees centigrade (typical).

Common-mode rejection of 85 dB (typical), open-loop gain of 80 dB (minimum), and a gain-bandwidth product of 3.5 MHz (typical) endow the ULN-3751Z with the characteristics required by its intended applications. A typical application as a non-inverting power amplifier is shown in Fig. 4. **ME**