Pyroelectric Infrared Detectors

Pyroelectric Effect

Since ancient times the pyroelectric effect has been known as a property of ferroelectric materials. It is based on a specific behavior of dielectric materials, the phenomenon of a permanent electrical polarization. When changing temperature of such materials, this polarization will increase, or decrease, we observe a charge displacement.

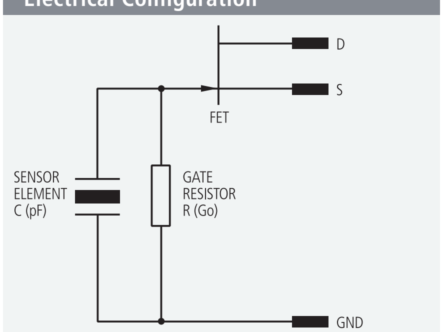
This pyroelectric effect is the basic principle for detectors that can recognize temperature variations. The characteristic value for the permanent polarization, called pyroelectric coefficient, disappears above the Curie point. The Curie temperature limits the operation temperature range for such detectors. Pyroelectric detectors do not require cooling.

Detector Design

Within our detectors, a thin slice of pyroelectric material is fitted with electrodes to form a capacitor. Incoming radiation will generate extremely low levels of thermal energy, so the pyroelectric current flow is rather small. It needs a circuit to convert this small current into a convenient signal. The traditional analog detectors apply a high ohmic resistor and a special low-leakage current FET to transform the high impedance of the detector material to a common output resistance. The pyroelectric element's capacitance and the high gate resistance of the FET form a RC circuit with a time constant of approx. 1 s., which makes the detector suitable for very low frequencies.

Figure 3

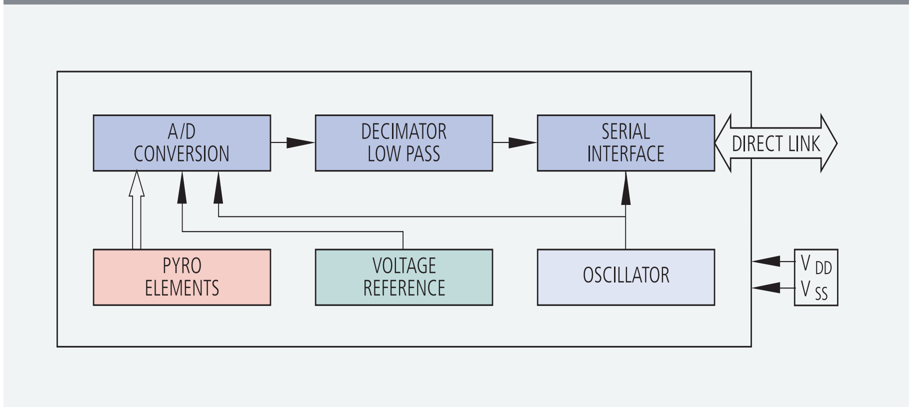
Electrical Configuration



Excelitas is the first to having introduced digital technology to Pyroelectric Detectors with it's DigiPyro® family. Here, a special ADC circuit provides amplification, A/D conversion and interfacing to the outside electronics.

Figure 4

DigiPyro®



Detector Construction

The pyroelectric material is placed on a special pc-board which provides thermal and mechanical isolation for the delicate pyroelectric material and provides space for the gate resistor and the FET. The connections are made either by wire bonding or conductive bonding. The whole pc-board is placed on to a TO header and closed with a TO cap, which has the relevant optical filter window. The window possesses a special infrared transmission characteristic, selected for the detector application.

Pyro Characteristics

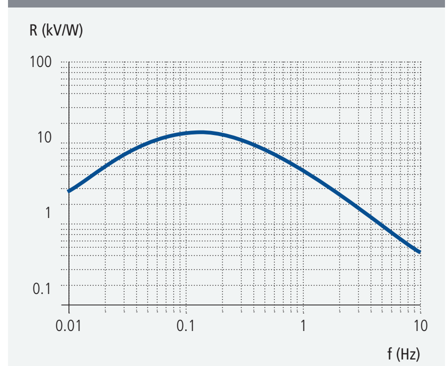
The most important electrical data of the IR-Sensor are its responsivity, balance and noise. Sometimes it is also useful to refer to NEP or D*.

Responsivity

The responsivity shows bandpass characteristics with a maximum at approx. 0.1 Hz radiation modulation. A typical curve „responsivity versus frequency" is indicated below as figure 5. Responsivity is measured in V/W by means of a defined black body radiator. Responsivity refers to the active sensor area and is usually tested at 1 Hz modulation frequency unless specified differently.

Figure 5

Transfer Function



Balance

The balance of a dual element detector indicates the common mode rejection also called matching between the two elements. It is an important value for the performance of dual element detectors, applied in motion applications, as it is a measure for distinction between moving and fixed objects. It can be specified either in V/W or in % of Responsivity.

Noise

The noise of the sensor consists of three parts: The basic thermal noise of the sensing material, the (Johnson) noise of the high ohmic resistor and the input noise of the FET. The total output of these tree parts is rather stable for temperatures below 40°C. Above this temperature, noise increases exponentially with temperature as can be observed with typical active electronic components. Noise is given in µV peak-to-peak or zero- peak. Similar to the dependence of responsivity on frequency, the noise values decrease with frequency from approx. 0.15 Hz to 50 Hz.

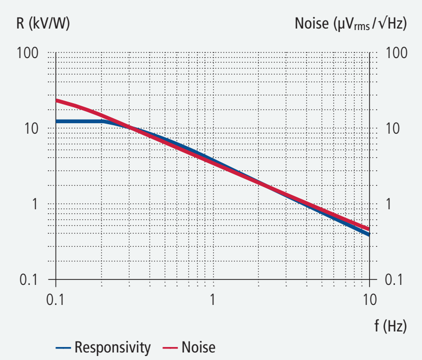
NEP, D*

The NEP value is a form of signal to noise ratio. The NEP value specifies the minimum radiation power that can be detected by the sensor, resulting in an output that just exceeds the noise. NEP refers to RMS values of signal and noise and in addition to the electrical bandwidth. The lower the NEP, the better the sensor is.

Sometimes also used for comparison of sensors, the Specific Detectivity (D*) allows the characterization of sensing materials. It is defined as reciprocal of NEP referring to the sensor area. Details of these parameters as function of the electrical frequency are given in Figure 6.

Figure 6

Responsivity, Noise vs. Frequency



Operating conditions

The storage and operating temperature range of the detectors is specified from -40°C up to +85°C. It needs to be noted that technical data usually reference room temperature and may vary within the specified temperature range.

Digital Pyrodetectors – a New Family

Pyroelectric detectors are AC type devices and give signals upon change of received Infrared radiation. Until today, all available detectors are analogue, i.e. they provide an analogue signal output. Excelitas is the first to introduce a family of detectors which differ from previous generations by offering a digital signal output.

With the DigiPyro® family Excelitas is offering digital Detectors for all these applications and configurations.

1.1 Integrated Electronics

The DigiPyro® series integrates the first stages of circuitry into the detector housing: Amplification of the signal, then the A/D conversion, which needs a voltage reference. Following an internal 10 Hz electrical low pass filter the serial Interface provides for the "direct link" communication which is a one wire bidirectional communication feature. The whole concept is running by its own internal oscillator, which determines the speed of the internal process. The direct link feature enables the user to have the host μC request the information and its resolution, so the host controls the communication speed.

1.2 From Analog to Digital

The DigiPyro series is the first pyroelectric detector family to display information in Bit form as opposed to μV signals of analogue detectors. To give a measure for comparisons of traditional detectors to digital versions, the rule of thumb for signal levels versus bit information can be used:

- Resolution: 1 LSB ≙ 6.5 μV
- Noise: 6 Count ≙ 39 μV (with band-pass)
- DC Offset 8192 Counts
- Digital Range: 0 to 16383 Counts

In a typical motion electronic application the expected signal voltages range from 100 μV to 500 μV, so the digital signal may range about 100 bit-count on to the offset. The dynamic range of the digital detector comprises the range from 511 counts to 15873 counts and with this it is wider than the most application based signal levels. Outside of this range the detectors offers an Out-of-Range Reset function.

1.3 Digital Zero Signal Line

As the pyroelectric effect generates positive and negative signal amplitudes, the detector circuitry needs an electrical offset to be able to process such signals. In all analog circuitry this value is the offset voltage, which is usually subtracted after the first amplifier stage.

With DigiPyros, the amplification is included already, and the internal voltage reference provides for the required offset. As to the user this offset appears as a digital zero line at about 8000 bit-count, it may vary in series from one part to the next. To recognize the zero line of the individual detector, the user may either use a digital band-pass or subtract the measured offset from the signal.

1.4 The Host Needs to Filter The Signal

The DigiPyro does not include any processing intelligence inside, unlike most analog Pyrodetectors the DigiPyro uses a direct communication with the hosting microcontroller without any analog hardware filtering (only the previously mentioned low-pass filter). Thus it becomes necessary to implement all necessary filtering by software filters within the hosting microprocessor of the unit.

Applications for Pyroelectric Detectors

Pyroelectric detectors had originally been designed as single element types for non-contact temperature measurement. During further research, dual element types were developed with multi-facet mirrors or Fresnel lenses entering the field of motion detection, starting as passive intrusion alarm (Burglar Alarm, PIR), followed by automatic light switches and security lights and lamps. The same concept is also applied with some automatic door openers.

Today the Environment and its protection is one of our most serious concerns. Features and instrumentation are required to measure and monitor all kinds of gas in our environment. One of the methods applied is the NDIR technique, a principle of measuring gas concentration by its absorption properties in the infrared range. Our detectors and sensors are a vital part of making our environment more safe, secure and healthy.

Most of PIR Motion detecting devices have been designed around Dual Element types, more advanced units apply Four Element "Quad" type configurations.

For Gas Sensing single element with narrow band filters are applied in single or dual channel configuration.