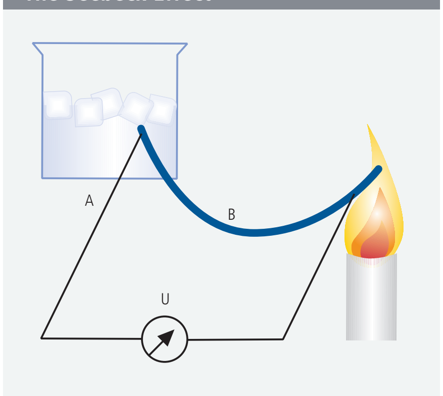
The Thermoelectric Effect

The thermoelectric effect today is known as reverse to the Peltier- (or Seebeck-) effect. By applying a temperature difference to two junctions of two dissimilar materials A and B, a voltage U which is proportional to the temperature difference is observed.

Figure 7

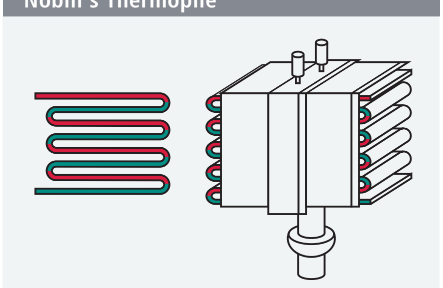
The Seebeck Effect



Leopoldo Nobili (1784 - 1835) first used the thermoelectric effect for IR radiation measurement using a "pile" of Bismuth and Antimony contacts.

Figure 8

Nobili's Thermopile



The measure of this effect is called the thermo-electric- or Seebeck- coefficient. For most conducting materials this coefficient is rather low, only few semiconductors possess rather high coefficients. Since the voltage of a single thermo-electric cell is very low, lots of such cells arranged in a series connection achieve a larger signal, making a "pile" of thermo-elements.

Excelitas Thermopile Design

Our thermopile sensors are based on the technology of Silicon Micromachining. The central part of a silicon chip is removed by an etching process, leaving on top only a 1 µm thin sandwich layer (membrane) of SiO2/Si3N4, which has low thermal conductivity. Onto this membrane thin conductors of two different thermoelectric materials (to form thermocouples) are deposited. Both conductors have alternatively junctions in the centre of the membrane (hot junctions) and on the bulky part of the silicon substrate (cold junctions). A special IR-absorption layer covers the hot junctions creating the sensors sensitive area.

When exposed to infrared radiation, the absorbed energy leads to a temperature difference between "hot" and "cold" contacts. According to the thermoelectric coefficient of the thermocouples a signal voltage is generated.

The Thermopile Construction

The sensor chip is mounted in good thermal contact on to a TO header. A transistor cap with infrared filter is sealing the sensor chip from the environment.

Excelitas's product portfolio includes detectors of various sizes, housings and infrared windows, and integrated sensors which include electronics that provide temperature compensation and calibration to a certain measurement range.

Excelitas offers unique constructions to deal with the thermal shock, referenced as ISO-thermal types.

Advantages

Thermopile Detectors do not require any mechanical chopper to sense infrared, thus they offer simple design possibility to infrared measurements.

Thermopile Characteristics

The most important properties of the Thermopile Sensor are it's responsivity, noise, field of view response time, and for calibrated Sensors the temperature range.

Responsivity

The responsivity shows low pass characteristics with a cut off at approx. 30 Hz.

Responsivity is measured in Volt per Watt by means of a defined black body radiator. Responsivity data usually quote with respect to the active detector area, and are given without the infrared filter. The data show a responsivity value, tested at 1 Hz electrical frequency.

Noise

The noise of the detector is dominated by the Johnson noise due to the resistance of the thermopile. Noise is given as RMS value in nV/√Hz.

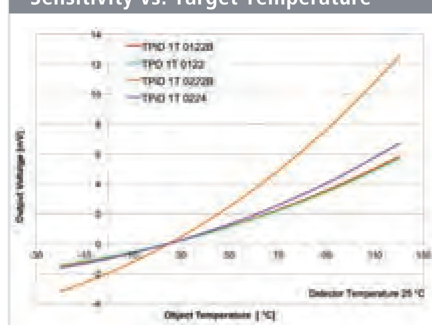
Sensitivity

The Data tables do also mention Sensitivity, as a characteristic output voltage versus target temperature at 25°C environment temperature.

The data are given with standard IR filter as per fig.2. Two are given: S(25/40) is 25°C environment, 40°C Black Body target and S(25/100), which is 25°C environment, 100°C Black Body target. Sensitivity is depending on the field of view of the detector construction. An example can be seen below for selected TPS series:

Figure 9

Sensitivity vs. Target Temperature



Thermistor Is Included

As temperature reference the thermopile detectors include a thermistor which senses the internal temperature.

For exact measurements the temperature of the detector housing (cold thermopile contacts) must be known. As a standard version 100kOhm thermistor inside the detector housing serves as the ambient temperature reference, optional 30 kOhm is available.

The dependence of the resistance on temperature can be approximated by the following equation:

$$R_T = R_R \cdot e^{B \cdot \left(\frac{1}{T} - \frac{1}{T_R}\right)}$$

R_T	NTC resistance in Ω at temperature T in K
R_R	NTC resistance in Ω at rated temperature TR in K
T	Temperature in K
T_R	Rated temperature in K
B	B value, material-specific constant of NTC thermistor
e	Euler number (e = 2.71828)

The actual characteristic of an NTC thermistor can be roughly described by the exponential relation. This approach, however, is only suitable for describing a restricted range around the rated temperature or resistance with sufficient accuracy.

For practical applications a more precise description of the real R/T curve is required. Either more complicated approaches (e.g. the Steinhart-Hart equation) are used or the resistance/temperature relation is given in tabulated form.

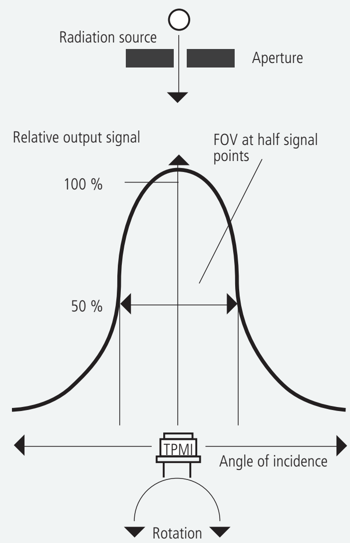
The Field of View

The most common use of thermopile detectors is non-contact temperature sensing. All target points within the field of view will contribute to the measurement signal. To meet requirements of different applications, Excelitas offers a broad range of sensors with different windows and optics.

The field of view data describe the dependence of signal from incident angles.

Figure 10

Field of View



The TPMI® family is available with different options on optical cap assemblies. We provide housing with aperture opening and filter window only, or with an infrared lens or also with integral mirror.

Such optical features define the viewing angle or as per definition the Field of View (FOV) of the sensor.

The FOV is defined as the difference of the incidence angles that allow the sensor to receive 50 % relative output signal, see also figure shown here, which is a sketch of a testing principle.

	Symbol	Parameter	Min	Typ	Max	Unit
Lens Type (L5.5)						
	FOV	Field of view		7	12	°
	OA	Optical axis		0	±3.5	°
	D:S	Distance to spot size ratio		8:1		
Integral Reflector Type (IRA)						
	FOV	Field of view		15	20	°
	OA	Optical axis		0	±2	°
Standard Aperture Type						
	FOV	Field of view		70	80	°
	OA	Optical axis		0	±10	°

Temperature Range

Excelitas offers sensors which include pre-amplification, ambient temperature compensation and calibration within a specific temperature range.

Thermopile Arrays

Further to it's range of Detectors and Sensors, Excelitas offers Line Arrays and spatial arrays based on Thermopile technology.

Applications for Thermopile Sensors

Thermopile Sensors have been designed for non-contact temperature measurement. The signal of the sensor follows the radiation energy receipt by the sensor. This enables the application of measuring surface temperatures without contact.

In many industrial process control units thermopile sensors are used to contactless monitor temperature or to serve as overheating protection feature.

The thermopile technology is also suited for domestic appliances such as food monitoring during automated defrosting, warming-up or cooking.

Same as our Pyrodetectors, the Thermopile Detectors with specific filter windows are used as sensing components making our environment more safe, secure and healthy.