USB Card Edition

HEIMANN Sensor
HEIMANN SENSOR GMBH

BostonElectronics

Infrared Measurement

Application Note

Every object emits electromagnetic radiation, which wavelength spectrum is dependent on its temperature. For an object without “color”, which means that no wavelength is selectively emitted or absorbed, the radiation spectrum is completely determined by the temperature alone. In this case, the total radiation power P_{obj} emitted by an object of temperature T_{obj} can be expressed as

$$P_{obj} = \delta * \varepsilon * ({}_{Tobj})^4$$

with *s* being the Stefan-Boltzmann constant and *e* the so-called emission factor (or emissivity) of the object. In the ideal case *e* has the value 1 (black body). For many substances the emission factor lies in the range between 0.85 to 0.95. The above equation is called the Stefan-Boltzmann law. It integrates the total quantity of radiation over all wavelength.
The *net* power P_{rad} received by the thermopile is related to the object temperature T_{obj} and to the temperature of the thermopile chip itself. This value is generally referred as T_{amb}, the ambient temperature.
Therefore the total heat power *Prad* received from the object at temperature T_{obj} is given to

$$P_{rad} = K * (\varepsilon_{obj} * T_{obj}^4 - \varepsilon_{abs} * T_{amb}^4)$$

The empirical factor *K* is a constant device factor.
The thermopile sensor delivers an output signal proportional to the heat flux. The heat balance equation is the basis of any quantitative temperature measurement (S -> voltage sensitivity).

$$U_{TP} = S * P_{rad} = S * K * (\varepsilon_{obj} * T_{obj}^4 - \varepsilon_{abs} * T_{amb}^4)$$

It describes that the output voltage is a function of the object and the ambient temperature. For a fixed ambient, the theoretical output voltage of the thermopile chip is proportional to T_{obj}^4. The T^4-dependence is only valid, if the sensor senses the whole electromagnetic spectrum with the same sensitivity.
Since in all practical situations the thermopile sensor never senses over all wavelengths with the same sensitivity, the pure T^4-dependence will rarely be seen. The real dependency can be better described by a polynomial regression of many polynomial factors and coefficients.
The output voltage also varies with the ambient temperature. Any IR temperate measurement system needs therefore to compensate this effect.
There are two possible ways to realize the ambient temperature compensation of the output signal. The analog way by employing an analog circuit. The circuit is designed in a way, that a voltage is generated, which matches exactly the loss or gain in output voltage due to any ambient temperature change.
For high accuracy applications a digital (numerical) calculation method is needed. In this case, the two signals, thermopile voltage and temperature reference signal are derived separately and fed into a microcontroller system, where the necessary calculations are made. The ambient temperature compensation can be performed using look-up tables or polynomial regression equations as a function of the ambient temperature, thermopile output and as result the object temperature. The calculation is related to a defined emissivity. The emissivity variation can be considered by a factor.