AN133 Application Note: Understanding infrared detection and common sensing technologies

1 INTRODUCTION

Energy in the form of infrared radiation (or IR) is all around us, offering deep insights. It is given off freely by any object with a surface temperature above absolute zero and so can be detected passively. IR sensors typically exploit this by converting incident IR energy into an electrical signal.

Two common approaches to this include using materials that generate a voltage correspondent to a temperature, known as thermocouples, and materials that exhibit spontaneous physical changes at the crystalline level that generate a current, or pyroelectrical material.

Both have their place in IR sensing, but are fundamentally different from each other. This results in each having advantages and disadvantages over the other, based on the specific application.

2 IR SENSORS

At a high level, IR sensors based on the absorption of energy in the infrared band to produce a thermal effect fall under two broad headings; thermocouple and pyroelectric. The energy incident on the detecting element is converted to electrical energy, the consequent electrical energy can then be detected and processed by integrated circuits.

The physical nature of these types of sensors means their response time is generally slower than other types of sensors based on photon detection.

The effects used by the thermal detectors described in this application note are both independent of the energy's wavelength. Furthermore, both will ordinarily employ some form of preamplification and may use compensation to limit the impact of microclimate fluctuations.

3 THERMOCOUPLES AND THERMOPILES

A thermopile is, as the name may suggest, a 'pile' of thermocouples arranged as a stack. Each thermocouple comprises two dissimilar but conductive materials which, when placed together, exhibit the Seebeck Effect. Each pair of conductors will produce a voltage in the region of µV, but when stacked in series, this voltage can increase to a point where it is much more easily detected.

A typical thermopile will have a 'cold' side and a 'hot' side; the cold side is maintained at ambient temperature, while the hot side is exposed to the IR energy produced by a hotter object. The difference in temperature will generate a measurable voltage, while compensating for the offset that would otherwise result from the ambient temperature.

The materials used are typically semiconductors in the form of polysilicon, doped to be either N-type or P-type. However other materials such as antimony and bismuth may also be used, which can result in better performance.

To use the correct terminology, the material on the exposed side of the thermopile is referred to as active, while the material that is shielded is called the compensator. Thermopiles are thought of as DC devices, as they generate a steady state voltage based on the temperature being measured or detected.

The rate of change of voltage is relatively slow, due primarily to their thermal mass. This thermal inertia is proportional to the device's thermal constant, which describes the rate at which thermal energy passes through the junctions. This can range from 10 to 100ms. As this is a physical constraint, a lower thermal constant would result in a lower output voltage, however because of this, thermopiles have a good DC response at frequencies below their thermal time constant. At frequencies above this, their DC response deteriorates, lowering their output voltage.

As they rely on electrons moving across a junction between two dissimilar materials, one of their main drawbacks is their susceptibility to – and fundamental reliance on – Johnson-Nyquist noise.

4 PYROELECTRIC SENSORS

The materials used in pyroelectrics can generate a charge based on a change in temperature. The charge is generated due to the material's propensity to change the orientation of its crystalline structure, before reverting to its steady state.

As opposed to thermopiles which consume constant power for operating whether they are detecting a signal or not, pyroelectrics only consume power when they are actively detecting a signal input and so they consume less power and are more power efficient.

As these devices are formed from dielectrics, they avoid the problem of Johnson-Nyquist noise, but this puts more of the design burden on the supporting circuitry. Specifically, because the sensor can be seen as a current source with high impedance, the low-level output will need to be amplified by either a discrete (transistor-based) or integrated (operational) amplifier; this is often the main source of noise, given the very small signal produced.

The pyroelectric effect isn't uncommon in various materials, but the three most often used for IR detectors are PZT (Lead Zirconate Titanate), LTO (Lithium Tantalate) and DLATGS (Deuterated Lanthanum-Alanine doped Triglycine Sulphate); each comes with its own figures of merit.

The asymmetric nature of the materials used means its polarization changes spontaneously when exposed to heat in the form of IR energy. The charge produced is transferred through electrodes to the amplifier circuit. The current change exhibited is the derivative of change in charge over time, given by dq/dt. This phenomenon is only apparent as the temperature is changing and, as such, pyroelectric sensors do not have a DC element to their output. Furthermore, each device will have a maximum current output, defined by the thermal time constant and related to the operating frequency. The thermal time constant can be set by design, based on the requirements of the target application.