AN136 Application Note: Understanding pyroelectric infrared detectors

1 INTRODUCTION

Infrared radiation or IR is energy emitted by any object above absolute zero. The scientific detection and exploitation of IR emissions has been an active area of research and development for over 200 years, yet it is still relatively new to some engineers. This is primarily because IR has, up until quite recently, been limited to niche applications. But the IoT continues to demonstrate how sources such as IR can be used to generate valuable data, which means it is breaking into new areas every day.

Understanding some of the basics behind pyroelectric sensing, one of the main methods for detecting IR, can help engineers adopt it to create versatile sensing solutions.

2 OUTPUT SENSITIVITY

A pyroelectric sensor generates an electrical output as a result of a change in thermal energy. The relationship between these two properties indicates the sensor's responsiveness. Incident IR energy is measured in Watts (per unit area), while the output is typically measured in either Volts or Amps. The responsivity of any sensor will therefore be given as wither V/W or I/W.

Because the sensor is reacting to a radiated wave that carries thermal information, both the temperature and wavelength of that wave will influence the level of output based on the responsiveness of the sensing element. Typically, a sensor will be calibrated or characterised using a controlled source, referred to as a Black Body.

The wavelength is particularly important, as IR energy occupies a bandwidth of between less than 1µm (Near IR) to up to 1000µm (Very Long Wavelength IR). No IR sensor available today could show significant response over the entire IR bandwidth, so most are optimised for a specific area of interest. NIR is close to visible light and many optical sensors are now able to detect greater levels of NIR, giving them better night vision. However, true IR sensors don't rely on visible light at all, and many sensors will operate around 1 to 5µm.

3 SIGNAL-TO-NOISE RATIO (SNR)

In the bandwidth of interest, the responsiveness of an IR sensor is still low, relative to the potential noise present. SNR is something all engineers working with very small signals need to deal with, and in this instance, it is typically a function of the voltage or current present at a particular wavelength and temperature.

Electrical noise, conventionally depicted as the product of the root mean square (or RMS) of the noise present, will be given for the square root of the sensor's bandwidth. The sources of noise will be numerous; as well as general noise present in the environment, localised sources will include electrostatic noise, thermal noise and vibrations (mechanical noise). The sensor itself will also generate noise due to the nature of its operation. This makes measuring noise difficult, putting some of the burden for mitigating its effects on the signal chain. However, in general, noise levels are relatively low in magnitude.

4 NOISE EQUIVALENT POWER OR NEP

Still in reference to SNR, the NEP depicts the power present when the SNR is 1. That is, NEP is the smallest output the sensor can produce that is not noise. In general terms, the smaller the NEP, the better the sensor.

In this respect, NEP is dependent on both the responsiveness of the sensor and the noise it generates, given as the RMS of the output voltage. It is measured in Watts per root Hertz, where root Hertz is the noise measurement bandwidth (see SNR, above).

While it is generally preferable to have a low NEP, if it is too low it would render the sensor so unresponsive that it would become difficult to use in any practical way.

5 SPECIFIC DETECTIVITY OR D*

Detectivity, normally denoted as D, is the reciprocal of NEP and is often used as a key comparative figure of merit. D-star – or more simply D* – is the normalised of specific detectivity. NEP, D and D* can be used to provide a way of comparing fairly the performance of sensors. D* is the reciprocal of the NEP (see above), normalised for the square root of the product of the area of the sensor and frequency bandwidth.

It should be noted that specific detectivity was originally intended to apply to quantum detectors, where noise power and noise signal are always proportional to the detector area; for thermal detectors such as pyroelectric, noise power and noise signal tend not to follow the same rule, so the figure of merit doesn't scale linearly with area. For this reason, caution should be exercised, as D* figures tend to underestimate the performance of smaller absorbing areas and overestimate the performance of larger areas.

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.

6 RESPONSE TIME

In general, the time it takes for any sensor to react to a change in input signal strength is finite and based on various factors, including the properties of the material used. Although pyroelectric IR sensors have an electrical time constant, which is dependent on the resistance and capacitance of the sensor, the response time is most dependent on its thermal time constant; the time it takes for the material to react to a change in thermal energy. Both time constants will impose limitations, but it is generally accepted that the two work in opposition; the electrical time constant limits maximum frequency response, while the thermal time constant defines a minimum response. This is important for assessing how fast a detector will respond to a flame signal or the time needed for a gas measurement to stabilise.