Thermopile Arrays Open Up A New World Of Automation Applications

INTRODUCTION TO IR SENSORS

Recently, the progress of uncooled Infrared (IR) Sensors has been remarkable due to Microelectronic Systems (MEMS)-based pixel structure, in which free standing thermal isolation structures are adopted with Thin Film IR Absorbers. Quantification of this energy allows users to determine the temperature and thermal behavior of objects. Infrared thermal sensing and imaging instruments make it possible to measure and map surface temperature and thermal distribution passively and non-intrusively. Infrared radiation is emitted by all objects with a temperature above absolute zero. For an object that has "no color", which means, no wavelength is selectively emitted or absorbed, the radiation spectrum is completely determined by the temperature alone. With rising temperature, the intensity at every wavelength of the radiation spectrum increases as well. This means that one can remotely determine the temperature of a body or object by measuring its radiated power.

Thermal Infrared Detectors, one type of IR Sensor, are distinguished by the advantages of a wide wavelength response, no requirement for cooling, high-temperature stability, high signal-to-noise ratio and low cost. Consequently, they are widely used in consumer products and in instrumentation. In a Thermal Detector, the incident radiation is absorbed to change the temperature of the material, and the resultant change in some physical properties is used to generate an electrical output. Thermal Sensors are differentiated between Pyroelectric and Thermopiles.

PYROELECTRIC VS. THERMOPILES

PYROELECTRIC. The heat radiation from the material in Pyroelectric Sensors generates a static voltage signal across the crystalline material. Under constant illumination, however, the signal declines which makes a periodical refresh necessary. Pyroelectric Detectors have slowly found their way into the consumer market through applications in burglar alarm systems and automatic light switches. Here the Detector senses the IR radiation from approaching people. In this case no chopper is needed, because an optics focuses the radiation from the moving people alternatively onto two detector crystals with opposite polarity. This generates a difference signal, which drives a switch or an alarm.

THERMOPILES. Thermopile Sensors, on the other hand, are comprised of a series of Thermocouples, each element being a thin wire made of two materials of different thermal activity. When a temperature difference occurs between the two ends of a wire, an electrical tension develops. The hot junctions are concentrated on a very thin common absorbing area, while the cold junctions are located on a surrounding heat sink with high thermal mass.

A Thermopile Sensor can be an instrument to remotely measure the temperature of objects and people. For this purpose designers need to think in terms of heat flow and not so much in terms of temperature when considering the use of a Thermopile Sensor in an application. If an object is seen with a certain temperature, immediately remember that it sends out heat flow of determined spectral characteristics and density. It flows from one place or object to another as a result of temperature difference and the flow of heat changes the energy levels in the objects.

It now depends on the area and the view field of the Sensor how much will be absorbed. The absorbed heat then will be led through the Thermocouples and the membrane structure, finally reaching the silicon rim and the housing bottom as the heat sinks. The heat flow through the material results in a temperature gradient. Thus the two Thermocouple ends – those located on the absorber and those on the silicon rim – will have different temperatures.

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Thermopile Array Advantages					
Detection Type	**Moving Object**	**Motionless Object**	**Moving Direction**	**Temperature Distribution**	**Thermal Image**
Thermopile Array	Yes	Yes	Yes	Yes	Yes
Pyroelement	Yes	No	No	No	No
Single-element Thermopile	Yes	No	No	No	No

Thermopile Temperature or Temp Sensors offer the advantage of non-contact temperature measurement, making them more and more popular over the standard contact-based Temp Sensors. Thermopile Sensors use infrared radiation versus conduction for heat transfer, which provides unique solutions that allow for new levels of performance and reliability in many constrained applications.

Engineers working on the Thermal Management of electronic equipment have long enjoyed the simplicity and convenience of the digital temp sensing ICs. The new integrated Thermopile Sensor ICs on the market provide the temperature results in the same convenient digital format. The continuous reduction in their power, size, and cost creates opportunities with consumer devices, medical instruments, office equipment and home appliances. The Pyroelectric and Thermopile types have dominated the low-end single-element Infrared Sensor market. Even though the former type has a large share in the single-element market, only the latter is suitable for Array Sensors.

INTRODUCTION TO THERMOPILE ARRAYS

While single element Thermopile Sensors and Pyroelectric Sensors do a good job at detecting the presence of warm bodies in a room, these simple Sensors won't detect motionless objects. Nor can they provide the direction of any movements within their field of view. To get around these sensing limitations, a more sophisticated sensing technology known as a Thermopile Array is required.

Thermopile Arrays consists of multiple IR sensing elements working together, instead of the single sensing element employed by conventional Pyroelectric motion detectors. These coordinated sensing elements and integrated signal processing capabilities allow the Thermopile Array to measure absolute temperatures as well as temperature gradients. Pyroelectric motion detectors, by contrast, can only pick up changes in temperature within their field of view, which is why they can't reliably detect bodies at rest.

The coordinated sensing elements of a Thermopile Array can do more than just read temperatures. They can also pick up the direction of movement—up, down, left, right and diagonally. Thermopile Arrays can even detect multiple people or objects as they move in different directions. They can also sense an object's proximity to the detector and handle simple gesture control tasks.

The Thermopile Array's enhanced sensing capabilities may be overkill for simple building automation applications, which have traditionally relied on low-cost Pyroelectric based motion detectors. Yet building automation systems are becoming more sophisticated and increasingly require the ability to sense motionless objects, multiple objects and direction of motion. These enhanced sensing capabilities can also support emerging object detection applications in industrial, medical and retail settings.

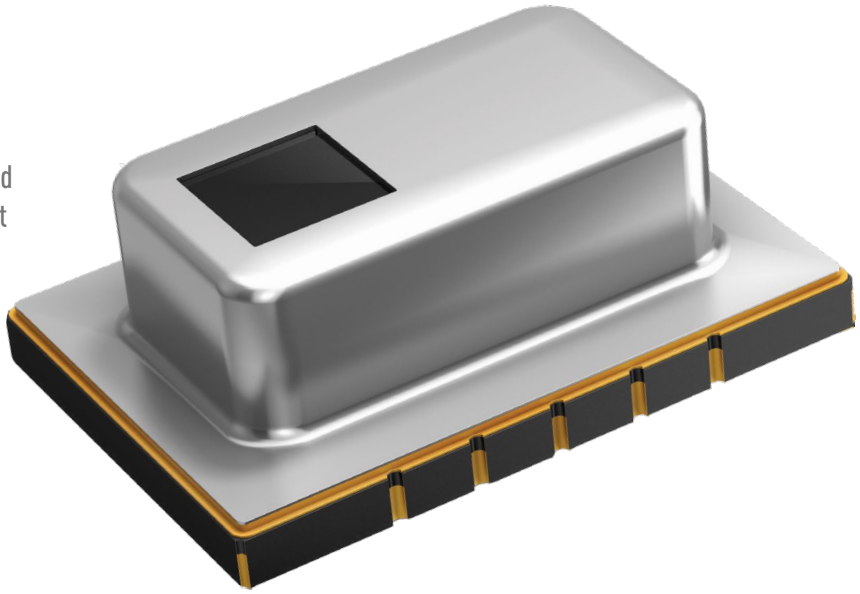
WHAT IS GRID-EYE™?

There are several variants of Thermopile Arrays available in different sizes and electronics packages, depending on the intended use. Panasonic's popular version, the Grid-EYE, currently consists of 64 MEMS thermopile elements arranged in an 8x8 grid on a single detector chip. An Integrated Circuit for signal processing and Thermistor round out Grid-EYE's onboard electronics.

The entire Thermopile Array fits within a reflow-compatible Surface Mount (SMD) package consisting of an RF-shielded metal cover, ceramic base and an integrated silicon lens through which the infrared energy passes. Grid-EYE offers I²C digital output for direct transmission of temperature values to a microprocessor.

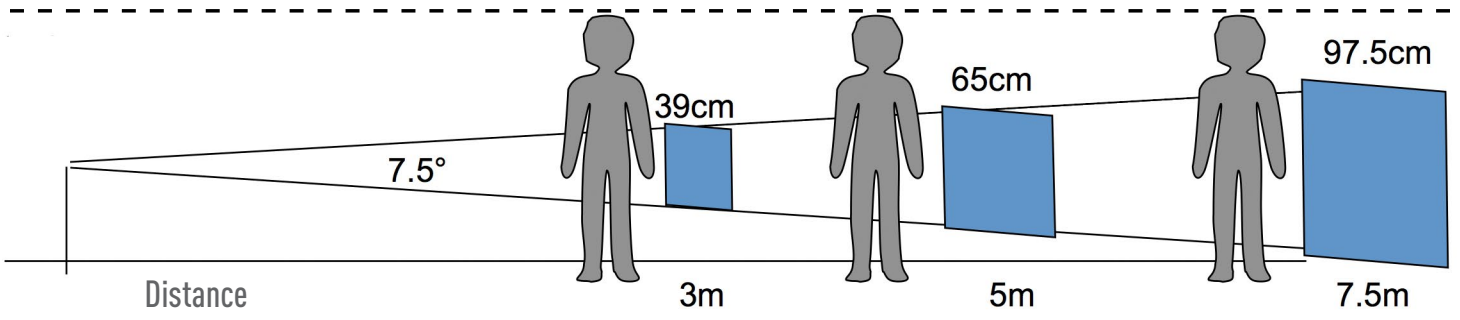
In operation, Grid-EYE first absorbs emitted thermal energy across a 60-degree field of view. Each one of the Array's 64 sensing elements converts the thermal energy it absorbs to a proportional output signal. All 64 temperature signals are then amplified, converted from analog to digital and referenced against an ambient temperature value supplied by the Thermistor. The Sensor electronics then push the resulting temperature readings to a microprocessor via the I²C interface.

Finally, the microprocessor performs calculations that map temperatures from the individual Thermopile elements into a complete thermal representation of the entire field of view.



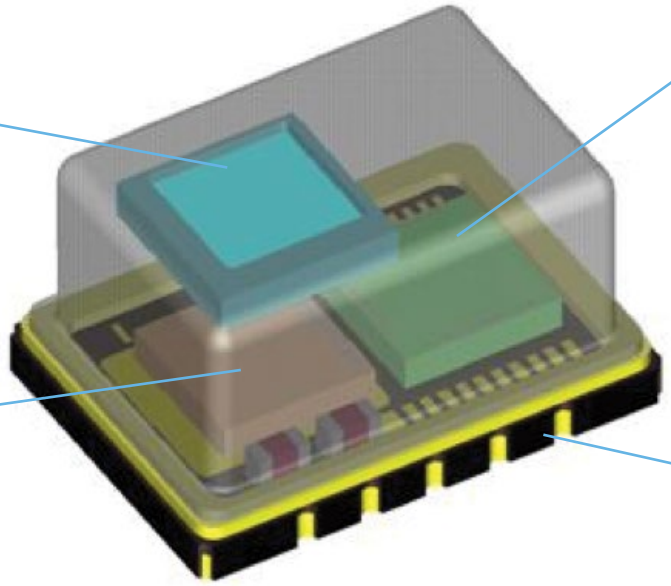
Changes in this representation over time indicate direction of motion. Panasonic's versions of Thermopile Arrays work in both horizontal and vertical orientations with a maximum recommended detection distance of 7 meters and frame rates up to 10 fps.

Depending on the application, Thermopile Arrays can be ordered in a high-gain version that measures temperatures to within ±2.5ºC while offering a temperature range of 0 to 80ºC. A low-gain version of the same 64-element Sensor offers a wider sensing range of –20 to 100ºC, but it offers a slightly reduced accuracy of ±3ºC.



Grid-EYE Sensors can detect human beings across a range of distances. The above diagram shows the field of view for one pixel.

Grid-EYE Features



Silicon Lens
- Image Formation

IR Detector
- 8 × 8 Pixels
- Thermal Insulation Structure Using MEMS Technology
- Infrared Absorption
- Thermoelectric Conversion

Mixed Signal Processing IC
- 64-Pixel Signal Readout
- Analog Amplification
- Analog to Digital Conversion
- Sensitivity Correction
- Correction for Temperature Effects
- Digital Communication

Ceramic Package
- Air Tight
- Radio Shielded
- Reflow Available

Grid-EYE Specifications

Specification	Value
Amplification Factor	High Gain
Power Voltage	3.3V +- 10%
Operation Mode (Selectable)	Normal, Standby, Sleep
Current Consumption	4.5mA (Normal), 0.8mA (Standby), 0.2mA (sleep)
View Angle	60° (x,y)
Temperature Accuracy	+-2.5°C (Typ Per Pixel)
Noise Equivalent Temperature Difference	0.16C @ 10Hz and 0.05C @ 1Hz
Frame Rate (Selectable)	1 Frame/Sec or 10 Frames/Sec
External Interface	I^2C (12bit)
Number of Pixels	64 - (Vertical 8 x Horizontal 8 Matrix)
Temp. Range (Measured Object)	0 - + 80°C
Op. Temp. Range	0 - + 80°C
Storage Temperature	-40 - +105°C
Size (mm)	11.6 (L) 8.0 (W) 4.3(H)

RICHER DATA ENABLES NEW APPLICATIONS

While Thermopile Arrays and traditional single-element Infrared Sensors both qualify as passive sensing methods, the two could not be more different from an application standpoint. While traditional PIR Sensors offer a low-cost way to detect the presence or absence of a warm body, that's as far as they can go.

By adding the ability to detect direction of motion and the presence of motionless bodies, Thermopile Arrays open up a world of automation applications that would be impossible with a traditional PIR Sensor. In fact, the closest points of comparison to a Grid-EYE Sensor aren't really single element PIRs but far more expensive active sensing devices or vision systems.

Applications that can benefit from richer Sensor data on motion, proximity and stationary object detection without the need for more expensive active sensing options include:

BUILDING AUTOMATION. Detecting whether people have entered or left a room is a fundamental task for simple building automation systems that seek only to turn lights and environmental system on or off automatically. With the enhanced motion and proximity data from a Thermopile Array, building automation systems with more complex logic become possible without moving to prohibitively expensive Sensors. For example, rather than a simple on-off automation of lighting controls, the automation system may use information on movement, number of occupants and position in a room to make targeted adjustments to lighting and air conditioning systems.

MANUFACTURING AND INDUSTRIAL. The use cases on the factory floor start with entryway and device control. Clean rooms in particular can benefit from these capabilities. Manufacturers are also testing Grid-EYE Thermopile Arrays as a way to sense the movement of goods on production lines—including one application that involves a liquid filling operation. Keep in mind, though, that the Thermopile Array's frame rate and response time will limit its utility in some high speed applications. The most promising applications on the factory floor involve the marriage of Thermopile Arrays with robotic systems or automated guided vehicles. The ability to detect a worker's location and direction of movement could allow them to work in closer proximity to robots while improving safety.

SECURITY. PIR-based Motion Sensors can give you a rudimentary head count as people walk through the Sensor's field of view. But Thermopile Array is a better approach for accurately counting a mix of moving and stationary occupants in a room. Detecting the direction of movement also has desirable implications in security applications.

MEDICAL IMAGING.Passive Thermopile Arrays can detect not just the presence of patients in medical imaging systems but also whether the patient is moving and correctly positioned in the machine. The Sensors can also control lighting within the imaging machine.

RETAIL. Many retailers already employ simple motion-based systems to count how many shoppers enter and leave a store. Thermopile Arrays can provide more detailed information about where shoppers spend their time in the store, revealing which aisles or brand displays are the biggest draws. At the same time, the passive Thermopile Arrays don't reveal personalized data as a vision-system would, which is important from a privacy standpoint.

These are just a few of the applications possible with Thermopile Arrays. Expect more in the future as automation developers take advantage of the Thermopile Array's ability to sense motionless objects, direction of movement and proximity without the high costs of active Motion Sensors and cameras.

CONCLUSION

Low cost and easy to manufacture, IR Detectors have been used in a wide diversity of markets such as construction, security, appliances, and industrial, and for a wide variety of functions, e.g. motion detection, temperature measurement, counting, fire detection, etc. Initially limited to single pixel Pyroelectric Detectors with a basic motion detection function, IR Detectors have progressively been used in more complex systems which diversified the market into higher-end applications such as temperature sensing, spectroscopy and more.

At the end of 2000, that diversification has been pushed further into the high end of the market by the introduction of Array Detectors. Multiple companies adopted a "technology push" strategy to introduce IR Detector Arrays either based on Pyroelectric technology or Thermopile technology. Coming from the MEMS industry especially Panasonic has ensured the domination of Thermopile technology on the Array Detector market by capitalizing on their knowhow in complex MEMS structure manufacturing and by introducing the Grid-EYE Sensor to the market.