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# Introduction to Low-resolution IR Imaging

The Thermopile Line Array Module family comprises of line sensors of 1x8-, 1x16- and 1x32-pixel. In addition we offer a spatial configuration of 4x4 pixels. All arrays are modular in design whereas the sensor offers an integrated lens and is mounted on a small PCB that provides the communication interface and connector. The modules use a common design concept: An Array Sensor is equipped with an internal temperature reference for correct target temperature determination and is connected to an integrated signal conditioning circuit. The signal is then fed to a microcontroller with an integrated $E^2$PROM on a small pcb. This µC is indispensable for the signal processing and interfacing. It further provides the digital output signal by SMBus representing real temperature data for each pixel.

Digital signal processing for temperature accuracy in combination with the numeric ambient temperature compensation algorithm, out performs any discrete solution. For many of our IR components we offer a patented ISOthermal concept which offers unusually high performance under thermal shock conditions.

Our new family of IR Image Sensors is based on high-performance Thermopile designs manufactured entirely in-house. It represents our approach of enabling high-volume applications at low cost. The IR Image Sensors provide spatial IR information without identification of objects and thus maintain people's privacy and data protection when monitoring areas. This approach is ideally suited for presence detection in smart homes, offices and hospitals.

## Thermal Imaging Introduction

The CoolEYE™ IR Image Sensor family offers a range of low cost IR camera modules designed for sensing of IR radiation in the mid-infrared range with low resolution. The camera is equipped with single lens optics resulting in a field-of-view of approximately 45° to 60°. The image as well as the the spot size of a single pixel becomes larger as distance increases. As long as the measuring area is larger than the pixel area the measurement result is independent from the distance between camera and object.

The Imaging information is provided to the user by means of an USB interface which also powers the CoolEYE IR Image Sensor. The USB protocol delivers digital representation of uncalibrated and unprocessed TP signal voltage. The voltage signal is converted by a 16-Bit ADC.

The following formula describes the transformation of IR radiation into an electrical signal as per the Stefan-Boltzmann law.

**Pixel Signal =** $\varepsilon * k * (T_{obj}^4 - T_{amb}^4) + V_{offset}$

*with:* ε = emmisivity of object
k = constant considering pixel sensitivity, optics, physical constants (S. Boltzmann)

**Tobj** = temperature of the object in the FoV of the thermopile pixel

**Tamb** = ambient temperature of the thermopile

**Voffset** = bias voltage and offset voltage from ADC input

The thermopile senses a temperature difference between the object temperature it is exposed to and its own (ambient) temperature. Depending on the sign of the temperature difference the thermopile provides either a positive or a negative output voltage. To allow processing of a bipolar signal with unipolar readout circuit the thermopile is biased.
The ADC sampling rate and data transmission rate of the CoolEYE IR Image Sensor is maximized to allow imaging at 10 frames per second for the largest imager size with 32x32 pixels. This complies with the thermal time constant of a thermopile pixel. If an application accepts slower frame rates it is recommendable to apply averaging of a certain number of consecutive frames to achieve better image quality with reduced noise.

The CoolEYE IR Image Sensor does not apply any signal processing and provides only raw data containing all the tolerances and imperfections that are inherent to thermopile technology, its fabrication, the signal processing as well as lens optics properties.

The CoolEYE IR Image Sensor will be calibrated during fabrication and individual calibration data for each pixel is stored in the Microcontroller. The calibration data can be read out via the USB interface and applied for signal processing in order to compensate for the effects of tolerances and to provide a homogenous and normalized signal for each individual pixel. The principle of signal processing is described in the following sections.

## Offset Correction

Each individual Pixel has a certain Offset failure which is mainly caused by fabrication tolerances in thermopile resistance and due to offset currents and voltages of read out electronics. The following formula shows the offset correction principle that should be applied.

**Offset corr $Pix_i$ Sig = $Pixel_i$ Signal - OffsCM - $Offs_i$**

*with:*
i = Pixel-and Parameter-index
Offset corr Pixi Sig =Off set corrected $Pixel_i$ Signal
$Offs_i$ = Individual Off set Voltage of $Pixel_i$
OffsCM = Bias Voltage Level

## Sensitivity Correction

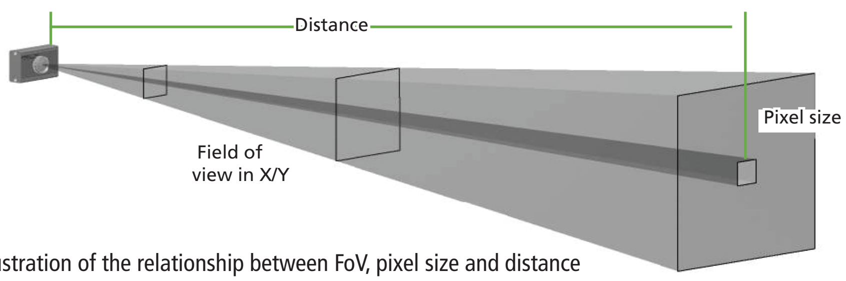
Each individual Pixel has a certain sensitivity range which is mainly caused due to fabrication tolerances, optical and detector material tolerances, as well as aberration effects of the optics. The following formula shows the sensitivity correction principle that is applied by the visualization software.

**$NormPixel_i$ Sig = (Offset corrected $Pixel_i$ Signal )/$Sensitivity_i$**

*with:*
$NormPixel_i$ Sig = Normalized $Pixel_i$ Signal
i = Pixel- and Parameter-index
$Sensitivity_i$ = Individual Pixel $Sensitivity_i$ in %

## False Pixel Correction

The imager can have up to 1.5 % of defective pixels. The indices of defective pixels that were found during production testing are stored on the CoolEYE IR Image Sensor. The defective Pixel information can be read out via the USB interface in order to replace missing signals from defective pixel with a signal that is interpolated from the neighboring pixels of the defective pixel.

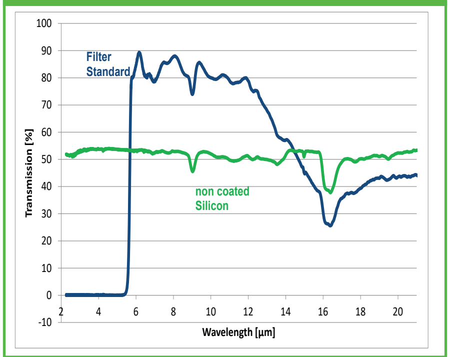



Ilustration of the relationship between FoV, pixel size and distance

## Lenses, Filters and Transmission

All IR Detectors, Sensors and Arrays need a special window that is transmissive in the working Infrared range. Most passive IR devices work in the mid-IR range which is above 5 µm. Thus we offer our products with either broad band window for low-cost applications or with coated IR filters. All arrays need a focussing lens close to the sensor. Excelitas offers array sensors with built-in lenses and with IR transmissive characteristics as shown above with filters.

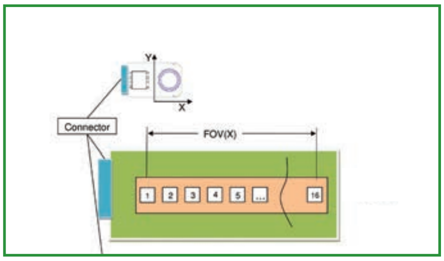
**Filter**

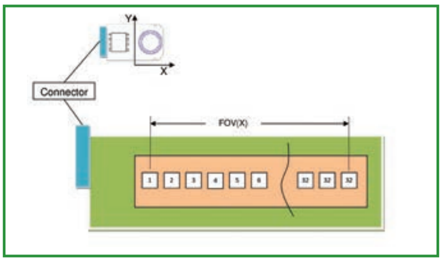



Depending on the lens applied, the arrays will offer different FoV. Several standard focal lenses will be available with our products to suit the application.

## Field-of-View of Line Arrays

For the line array family presented herein, two types of lenses will be applicable. For measurement applications we offer L5.5 whereas for presence detection applications, where a wide FoV is desirable, L3.9 is applied. As to the field of view definitions see the diagram below.

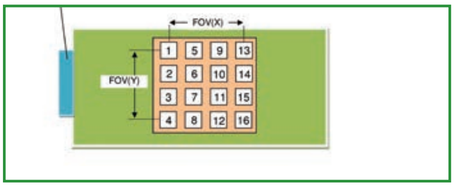


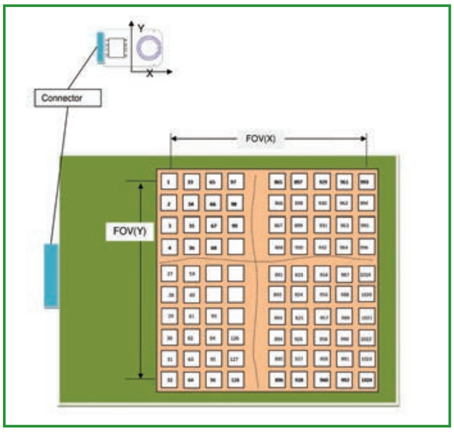




## FoV for 2-Dimensional Arrays

The 2-dimensional array family presented herein is designed for the primary purpose of presence detection and automatic processing. Thus, sometimes lesser pixel number is better for fast and easy image processing.

As for FoV, the individual Array Module is equipped with an appropriate lens to enable a wide field-of-view. For the definitions see the diagrams below.




## Pixel Number 2-Dimensional Arrays

IR Sensors and Arrays have been used in military applications for many years. Often, even cooled devices were applied to generate high-resolution images with a large number of pixels. Most familiar technology is the microbolometer. Devices are available now even as uncooled sensors, however, they always need an on-time calibration to present an accurate information.

For smart home presence detection those sensors will not be very useful. Too much processing power and slow response will be the downside of high-resolution Imagers.

Excelitas thus presents its family of CoolEYE arrays featuring a reduced number of pixels with high-temperature resolution. The applied technology will not rely upon on-time calibration. The 2-D array family presented herein is primarily designed for presence detection and automated processing. Thus, less pixel are better for faster image processing.

The illustration below shows the spatial resolution of 1000 pixels in a fairly wide FoV and distances up to 8m. We can recognize that in the full range the shape of human being may be recognized and detected with more than sufficient details.

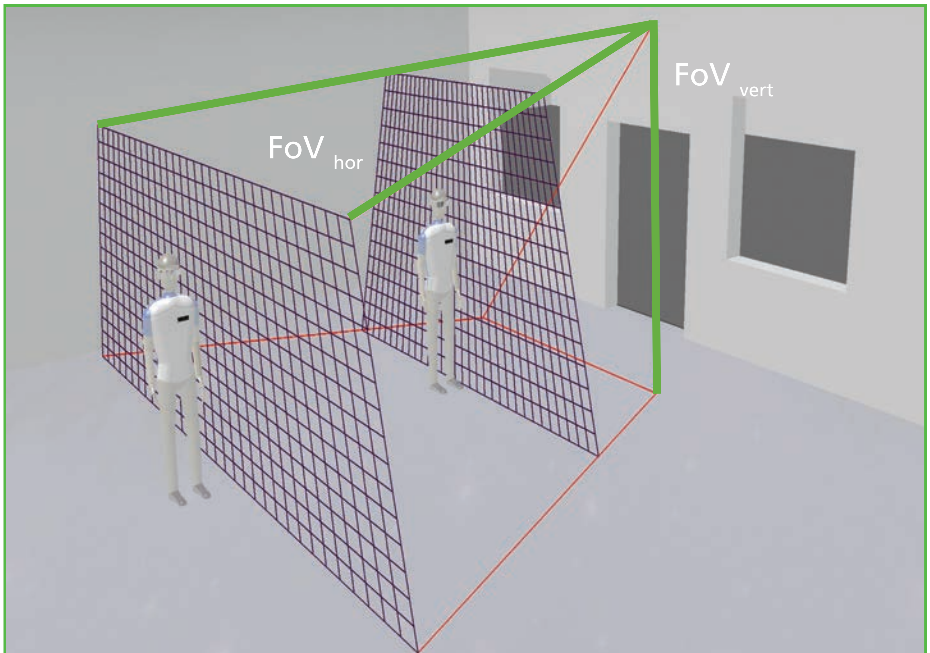



Illustration of 1000px FoV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