Infrared Basics

All solid bodies when having temperatures above the absolute zero (-273 °C) emit electromagnetic waves. The range of longer wave lengths beyond the visual spectrum is referenced as infrared radiation. Scientist Wilhelm Wien (1864–1928) has described the relation between a solid body's temperature and its emitting peak wave length by following equation:

λ_{max} =2898 / T
T = Temperature in K (Kelvin)
λ = Wavelength in µm

With this formula the peak emission wave length of any material may be calculated.

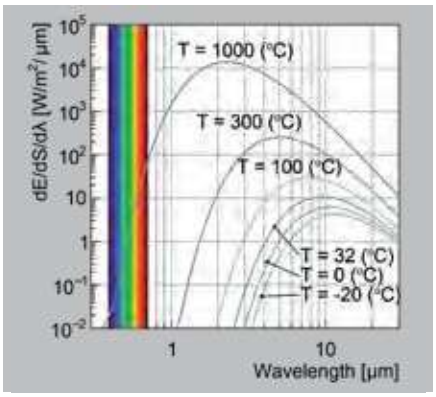


Fig 1:Radiated Energy vs. Wavelength

Max Planck (1858–1947) has described the relation between a solid body's surface temperature and its emitting wave length.

According to Max Planck, the intensity curve of all emitted wave lengths for a solid body is rather broad. For the case of an ideal emitting body the emission spectrum is shown in Figure 1 for selected surface temperatures. Ideal emitters are called "black body".

With the naked eye we can see hot objects at about 1000°C glow red and we can feel the heat, whereas colder objects that cannot be seen glowing, still may emit heat. The human eye's sensitivity is limited to the so-called visible range of 300 to 750 nm. To detect the non-visible infrared-radiation, we need sensors that work in the range beyond, which is 1µm and further. Typical sensors for motion detection use windows 5µm to 14µm.

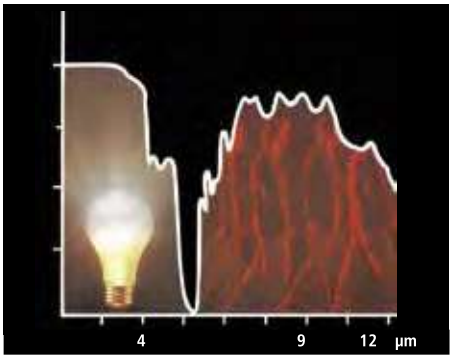
Temperature Dependence

The radiation sent from emitting bodies is temperature dependent. There is another parameter which determines the body's surface property. With this Emissivity factor we can estimate the total emitted radiation power P of a warm object:

$$P_{net} \sim \varepsilon T^4_{obj} + (1-\varepsilon)\, T^4_{amb}$$

The radiated Power is proportional to its surface temperature T [Kelvin] to the Power of 4 and its emissivity. The emissivity ε of the surface of an ideal black body is 1. An opaque object with an emissivity lower than 1 (gray body) will additionally reflect the temperature of the ambient.

Hot objects generally dominate any total radiation over cold objects due to the power of 4 dependence.



Spectral working range versus visible light

The Real World

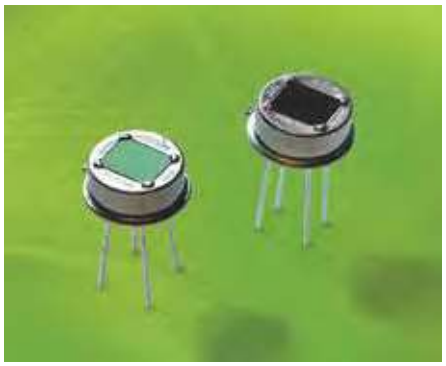
The human skin as well as water have a very high emissivity in the far infrared of above 0.9. The peak emission for human skin temperature is around 10µm and it is barely radiating below 3µm.

Typically, specular objects are highly reflective in the infrared region and contribute less to the total radiation received from the objects surface temperature. Diffuse objects can have a high emissivity and are better suited for measuring their surface radiation.
We further need to consider that properties in the visible spectrum may totally differ from the properties in the IR spectrum.

A human head with a surface temperature of approx. 35°C or 308 K calculates into a peak wavelength of 9.4 µm; the body of a cat at 38°C temperature calculates to 9.3 µm. Pets like cat or dogs have similar body temperature. By this, their radiation is very similar to human, and it is not possible to distinguish humans from cats or dogs by their infrared spectrum.

Infrared Detectors

With detectors for the infrared spectrum there are two major classes by their physical principles: Photon Detectors and Thermal Detectors. Photon Detectors convert radiation directly into free electrons. Thermal Detectors receive radiation, transfer it to raising temperature of the sensing material which changes its electrical property in response to the temperature rise. Photon Detectors such as Photodiodes and Phototransistors range from visible to near infrared.



To detect the radiation of objects at typical ambient temperatures, and slightly above, simple photonic detectors based on PN-doped silicon structures such as CCD or CMOS will not work. Advanced technologies, specific for that use, separate into two major classes: **Photon Detectors** and **Thermal Detectors**. Photon Detectors convert radiation directly into electrons and are typically made from cooled exotic semiconducting materials - these detectors are not the scope of this overview.

Thermal Detectors receive radiation, transfer it to raising temperature of the sensing material which changes its electrical property. The spectral range is also dependant from the absorbtion of the material. These detectors have a broad response from below visible light up to over 100µm. Thermal Detectors are sensitive to the net radiation.

$$P_{net} - \varepsilon T^4_{obj} + (1-\varepsilon)\, T^4_{amb} - T^4_{sens}$$

Fitted with special infrared windows as spectral filters they work in the mid to far infrared range without ambient visible light interference. Excelitas offers a variety of thermal detectors, including Pyrodetectors and Thermopile Detectors. Pyroelectric sensors require a modulated radiation over time in order to respond with a charge flow. While the response of pyroelectric sensors is generally higher than response of Thermopiles, Thermopiles provide a constant voltage output, which is proportional to the net radiation.

Both technologies respond to radiation changes within several milliseconds making them optimal to detect fast temperature modulations. Details are discussed in the corresponding sections.

Filters for Infrared Sensors

Material used for filters and windows must be transparent in the wavelength of interest. Glass for example is generally not suited to sense the temperature of human skin since it absorbs wavelengths above 4µm. Common materials with a broad transmission range are Germanium and Silicon for being used as the internal filter window for IR Sensors. For outside protection only few materials are suitable. Among many plastics, only PP or HD-PE can be used as protection or as fresnel structured optics for presence and motion detection.

Detectors by Excelitas Technologies are fitted with special infrared windows used as spectral filters. They work in the mid to far infrared range and usually block the visible range. Common applications in infrared reference wavelengths from 2 to 20µm. Thus the many windows allow transmission from 5-14µm. Infrared windows for pyrometric applications are defined for the atmospheric window. To avoid atmospheric absorption long range pyrometers apply a sharp cut-on/cut-off window of 8-14µm (G9).

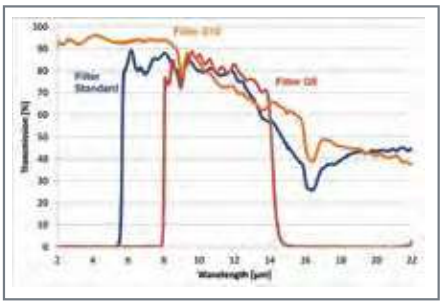


Fig.2

In Fig.2 we show the graph for standard infrared window and the "G9" window. For the special application of Gas Sensing by non-dispersive infrared absorption (NDIR) of a modulated radiation source we offer narrow band filters. The appropriate narrow band optical filters enable detection of Carbon Monoxide, Carbon Dioxide, Natural Gas and other environmental gases, as well as some technical gases. Please refer to the section dedicated to Gas Sensing for details.

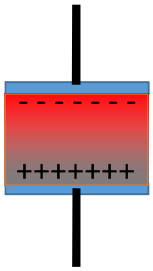
Environmental Remarks

Thermal Detectors achieve best results at thermally stable conditions. This applies not only to the detector but also to the environmental conditions. Temperature gradients and temperature changes through direct and indirect heat transfer as well as other thermal influences shall be minimized in order to obtain best measurement results.

Pyroelectric Effect

Since ancient times the pyroelectric effect has been known as a property of ferroelectric materials. It is based on a specific behavior of dielectric materials, the phenomenon of a permanent electrical polarization. When changing temperature of such materials, this polarization will increase or decrease. We observe a charge displacement when applying electrodes to the surface.

This pyroelectric effect is the basic principle for detectors that can recognize temperature variations. The characteristic value for the permanent polarization, called pyroelectric coefficient, disappears above the Curie point.

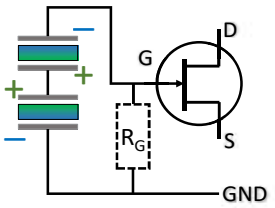


The Curie temperature limits the operation temperature range for such detectors. Pyroelectric detectors do not require cooling in order to operate.

Detector Design

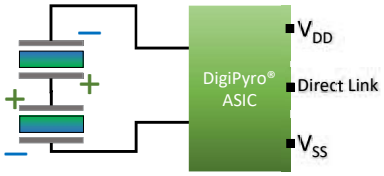
Within our detectors, a thin slice of pyroelectric material is fitted with electrodes to form a capacitor. To compensate for ambient temperature changes, typically pairs of capacitors in opposed orientation are used.

Incoming radiation on one of the two paired elements will generate extremely low levels of thermal energy, so the pyroelectric current flow is rather small. It needs an amplification circuit to convert this small current into a convenient signal. Traditional analog detectors apply a high ohmic resistor and a dedicated low-leakage current FET in order to transform the high impedance of the detector material to a common output resistance. The pyroelectric element's capacitance and the high gate resistance of the FET form an RC circuit with a time constant of about 1 second.
At very low frequencies the self-discharge dominates: with the electrical and thermal time constants the detector forms a band-pass like transfer function.



Dual Element Analog Detector with source follower cuircuit

Excelitas is the first to have introduced digital technology to Pyroelectric Detectors with its DigiPyro® family. A high-resolution ADC circuit provides direct analog to digital conversion. DigiPyro will drastically reduce your development and testing time. No further amplification chain is required and electro-magnetic interference (EMI) is significantly less severe.



Motion Detection

The most typical application of pyroelectric sensors is motion detection. Since only one of two compensating elements must be irradiated to generate a signal, pyroelectric sensors are placed behind optical components such as mirrors or multi-faceted Fresnel lenses.

A lens or mirror projects the thermal signature of the object onto the elements. Generally for long distance sensing long focal lengths are recommended.

For wall (horizontally) mounted applications, dual-element sensors (PYD) will give the best signal-to-noise performance. Optionally four (PYQ) element sensors with dual output can be used allowing an advanced differential signal analysis.

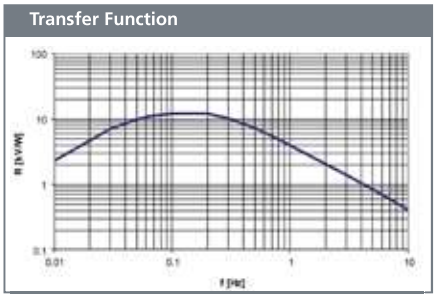
Ceiling mounted applications require four element sensors with diagonally oriented elements. Best signal-to-noise performance is achieved with two separate channels, one for each element pair. As a cost effective alternative, a design with all four elements in a row with a single output can be used.

Detector Characteristics

The most important electrical data of the IR-Sensor are its responsivity, match and noise. Some special applications refer to NEP or D*.

Responsivity

As shown before, responsivity features a natural band-pass behavior with a maximum at about 0.1Hz radiation modulation. Excelitas measures the responsivity in front of a modulated black body while covering one of the two compensated elements. The result is provided as a voltage per radiation power V/W at a 1Hz modulation frequency, unless specified differently. That unit is not normalized to the active sensor area, which means that small element sizes will provide larger responsivity values as compared to large elements when using the same pyroelectric material.

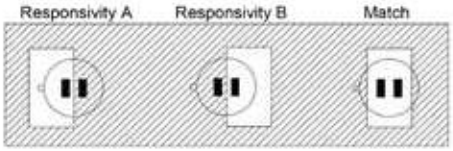


Example of transfer function of Dual Element Pyro

Match/ Common Mode Balance

The match between compensating elements of a pyroelectric detector indicates the ability for the "so-called" common mode rejection.

It is an important value for the performance of detectors, which are used for motion detection. It measures how well a signal can be suppressed when the origin is changing its temperature but not its position in the field-of-view. Stationary objects such as heaters will be rejected well when the match is low. The match is typically given as a signal by all illuminated elements of a detector relative to the responsivity of one element.

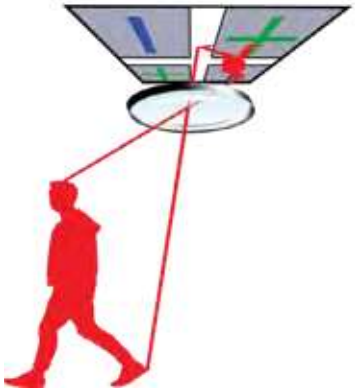


Noise

The noise of the sensor consists of three parts: the basic thermal noise of the sensing material, the (Johnson) noise of the high ohmic resistor and the input noise of the FET. The total output of these three parts is rather stable for temperatures below 40°C. Above this temperature, noise increases exponentially as a function of the temperature like it can be observed with typical other active electronic components. Noise is given in µV peak-to-peak or zero-peak.

Environmental Conditions

High humidity, condensation, dust or other radiation absorbing residuals will influence the detector performance. For the application of remote temperature measurement, generally it is required to have the sensor and all components around it at the same temperature as the ambient in order to calculate the correct absolute object temperature.



Example for a Four Element Detector

For the application of motion detection, the objects temperature must differ from the ambient in order to modulate the net radiation power over time.

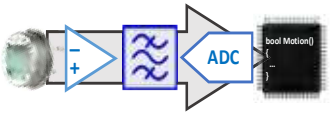
Electro-Magnetic Interference

Like in any other component with small signals, EMI can influence the measurement results of thermal detectors. Metal TO-cans perform the best in difficult conditions. Excelitas digital solutions achieve the highest EMI tolerance since they do not require any additional amplification of analog signals.

The Analog Approach

A typical motion detection layout consist of five components. The analog detector signal requires an amplification stage in order to be processed. The amplification factor is typically above 1000 and is very sensitive to any electro-magnetic interference. It requires a very careful design and is very often the topic of last minute design changes when it comes to testing for conformity with international regulations.

Moreover, the signal is floating when ambient conditions change even slightly. Hence, a band-pass filter of typically 0.4 Hz to 10 Hz is applied prior to digitization with an ADC input stage. Finally, the signal analyzed for motion signatures meeting user defined criteria.



PYD 1378 • PYD 1388 • PYD 1398

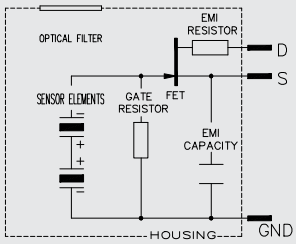
Dual-Element Pyrodetectors

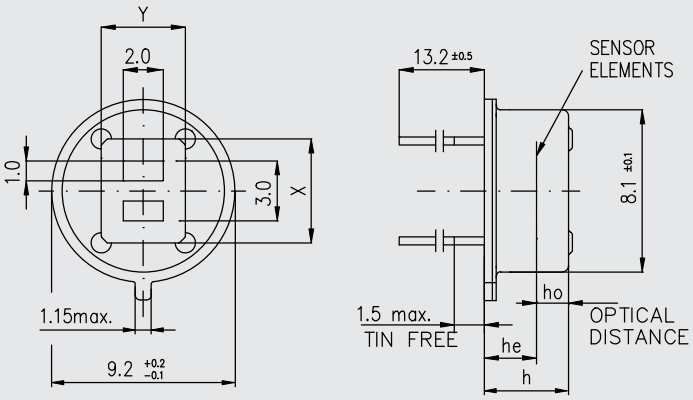
This Dual-Element Detector family offers standard TO-5 housings with varying window sizes. Whereas PYD 1378 is designed for economy and features a small optical window, PYD 1388 offers standard window size and is regarded as the standard Dual-Element Pyrodetector which is well suited for all kind of motion detection applications.

PYD 1398 with its even larger window size provides superior protection against white light interferences. PYD 1388 and PYD 1398 further provide an added 1kOhm Drain Resistor, which improves resistance to electromagnetic interferences, that may be introduced into the unit power supply. This makes PYD 1398 ideally suited for intrusion alarm applications.

Features and Benefits

- TO-5 metal housing
- Different window sizes
- EMI protection
- Suited for alarms and light switch applications





PYD 1378 - PYD 1388 - PYD 1398

Parameter	Symbol	PYD 1378	PYD 1388	PYD 1398	Unit	Remarks
Responsivity, min.	R_{min}	3.3	3.3	3.3	kV/W	f = 1 Hz
Responsivity, typ.	R	4.2	4.2	4.2	kV/W	f = 1 Hz
Match, max.	M_{max}	10	10	10	%	
Noise, max.	N_{max}	50	50	50	μV_{pp}	0.4…10Hz/20°C
Noise, typ.	N	25	25	25	μV_{pp}	0.4…10Hz/20°C
Source Voltage		0.2 … 1.55	0.2 … 1.55	0.2 … 1.55	V	47 KΩ, 20°C, V_{DD}=10V
Operating Voltage		2.0…10	2.0…10	2.0…10	V	47 KΩ, 20°C
Field of View, horizontal	FoV	71°	95°	100°		unobstructed
Field of View, vertical		71°	87°	100°		unobstructed
Filter Size	X/Y	4.0 / 3.0	4.6 / 3.4	5.2 / 4.2	mm	
Housing height	h	4.2	4.2	4.2	mm	
Optical Element Location	he/ho	3.2 / 0.75	3.2 / 0.75	2.6 / 0.95	mm	h0= optical

PYD 1384 • PYD 1394

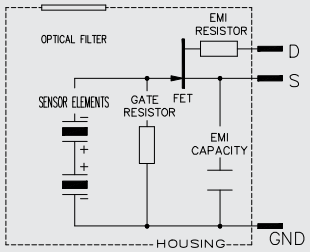
Dual-Element Pyrodetectors

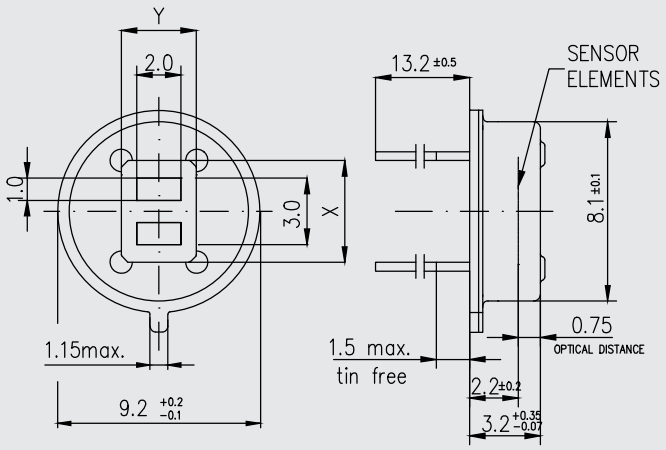
This Dual-Element Detector series represents the low-profile, TO-39 housing version of the standard Pyro family and is available with two different window sizes. The PYD 1384 is designed for optimal economy in cost-sensitive applications while the PYD 1394 offers the standard window size for enhanced performance. The 1kOhm Drain Resistor included helps to reduce sensitivity against electromagnetic disturbances.

In both models, the low-profile TO-39 housing saves space and enables applications which require lens optics with small focal lengths. It is very suitable for placing two detectors at juxtaposed angles to one another other on a single PCB to provide wider fields of view such as 180°.

Features and Benefits

- TO-39 metal low-profile housing
- Different window sizes
- EMI protection
- Suited for motion detection





PYD 1384 - PYD 1394

Parameter	Symbol	PYD 1384	PYD 1394	Unit	Remarks
Responsivity, min.	R_{min}	3.3	3.3	kV/W	f = 1 Hz
Responsivity, typ.	R	4.2	4.2	kV/W	f = 1 Hz
Match, max.	M_{max}	10	10	%	
Noise, max.	N_{max}	50	50	μV_{pp}	0.4…10Hz/20°C
Noise, typ.	N	25	25	μV_{pp}	0.4…10Hz/20°C
Source Voltage		0.2 … 1.55	0.2 … 1.55	V	47 KΩ, 20°C, V_{DD}=10V
Operating Voltage		2.0…10	2.0…10	V	47 KΩ, 20°C
Field of View, horizontal	FoV	95°	110°		unobstructed
Field of View, vertical		87°	110°		unobstructed
Filter Size	X/Y	4.6 / 3.4	5.2 / 4.2	mm	
Optical Element Location	he/ho	2.2 / 0.75	2.2 / 0.75	mm	h0= optical

PYQ 1398 • PYQ 1348

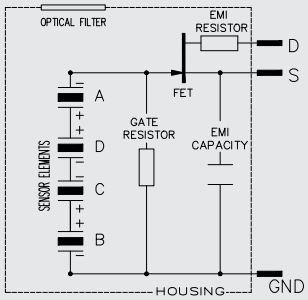
Quad-Element Detectors, low-cost

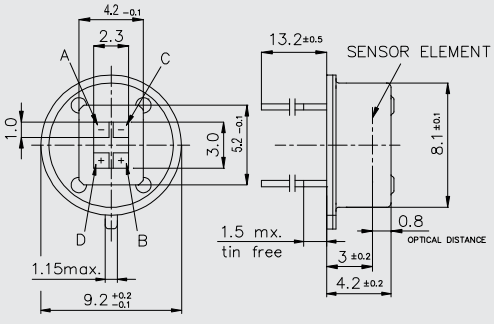
This series of Four-Element "Quad" Detectors provides all four elements connected to one common output. This configuration enables specific applications in ceiling-mount locations when applied with suitable lens- or mirror-optic designs. Two different window options are available to accommodate different fields-of-view. PYQ 13## Quad-Element Detectors further provide added 1K Ohm Resistor in the drain connection and a built-in capacitor to ground. Both contribute to reduced sensitivity to electromagnetic disturbances.

The standard geometric element layout offers equal distance and spacing with cross polarity. Customized options of other polarities and geometries are available upon request.

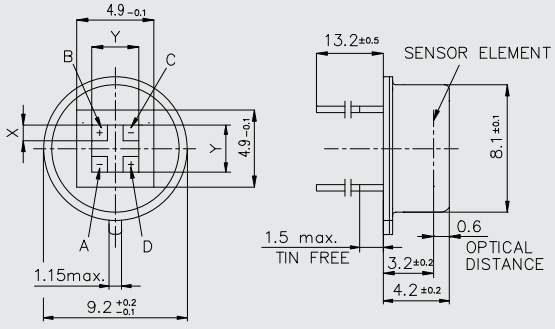
Features and Benefits

- TO-5 metal housing
- Different window sizes
- EMI protection
- Designed for ceiling mount motion detection





PYQ 1398 Housing



PYQ 1348 Housing

PYQ 1398 - PYQ1348

Parameter	Symbol	PYQ 1388	PYQ 1348	Unit	Remarks
Responsivity, min.	R_{min}	5.4	5.4	kV/W	f = 1 Hz
Responsivity, typ.	R	6.5	6.5	kV/W	f = 1 Hz
Match, max.	M_{max}	15	15	%	
Noise, max.	N_{max}	100	100	μV_{pp}	0.4…10Hz/20°C
Noise, typ.	N	40	40	μV_{pp}	0.4…10Hz/20°C
Source Voltage		0.2 … 1.55	0.2 … 1.55	V	47 KΩ, 20°C, V_{DD}=10V
Operating Voltage		2.0…10	2.0…10	V	47 KΩ, 20°C
Field of View, horizontal	FoV	103°	124°		unobstructed
Field of View, vertical		100°	124°		unobstructed
Filter Size	X/Y	5.2 / 4.2	4.9 / 4.9	mm	

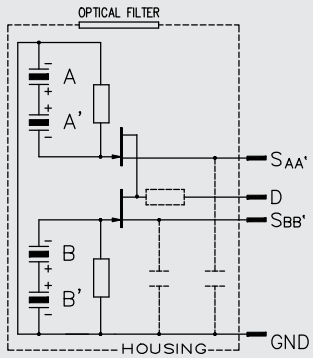
PYQ 2498 • PYQ 5448

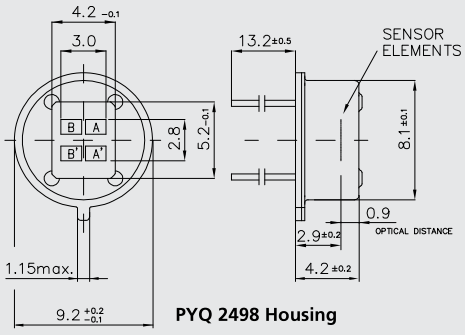
Quad-Element Pyro, Dual-Channel Output

This Detector family is distinguished by two pair of sensing elements, each with it's individual output. As to the spacing of the sensing elements, various designs are available. The TO-5 housing is provided with suitable window size to accommodate the field-of-view of the element configuration.

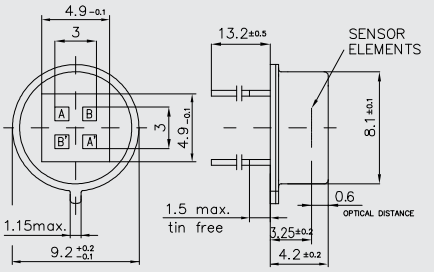
Features and Benefits

- TO-5 metal housing
- Dual Channel Output
- Square / rectangular window options
- Customized Element configuration options
- Suitable for wall mount and ceiling mount applications





PYQ 2498 Housing



PYQ 5448 Housing

PYQ 2498 - PYQ 5448					
Parameter	**Symbol**	**PYQ 2498**	**PYQ 5448**	**Unit**	**Remarks**
Responsivity, min.	R_{min}	3.5	4.4	kV/W	f = 1 Hz
Responsivity, typ.	R	5.5	8	kV/W	f = 1 Hz
Match, max.	M_{max}	15	15	%	
Noise, max.	N_{max}	75	75	μV_{pp}	0.4…10Hz/20°C
Noise, typ.	N	30	30	μV_{pp}	0.4…10Hz/20°C
Source Voltage		0.2 … 1.55	0.2 … 1.55	V	47 KΩ, 20°C, V_{DD}=10V
Operating Voltage		2.0…10	2.0…10	V	47 KΩ, 20°C
Field of View, horizontal	FoV	110°	95		unobstructed
Field of View, vertical		87°	95		unobstructed
Filter Size	X/Y	5.2 / 4.2	4.9 / 4.9	mm	

From Analog to Digital

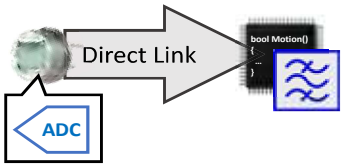
Excelitas Technologies was the first to introduce a digital interface to pyroelectric sensors. The DigiPyro® family features a highly sensitive ADC input stage, which does not require further amplification. This allows for the lowest supply currents and is therefore ideal for energy efficient, battery operated applications. Selecting a digital sensor in a TO-can will significantly expedite your design process and lower the susceptibility to EMI. This is particularly important when you design a device with wireless communication features. Excelitas offers several digital solutions meeting various requirements.

DigiPyro

The simplest DigiPyro solution consists of a high-resolution ADC within the component housing. The data is transferred digitally through the proprietary direct link interface to the host system. In addition, an internal temperature reference channel is implemented in order to monitor component temperature changes. Excelitas offers one-channel (PYx x7xx series) and two-channel (PYx x8xx) solutions. While one-channel is optimal for dual-element sensors, two-channels allow for differential signal analysis with four-channel detectors.

Typically, a digital band-pass filter is applied on the host system's analysis code prior to the search for user defined motion criteria.

Direct Link Interface

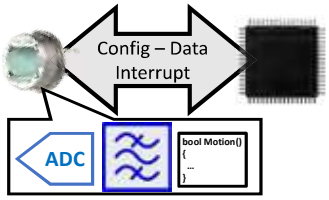


The Direct Link Interface was specially designed for pyroelectric sensors. This one wire interface does not require any external clock since communication speed is controlled by the host system. Either the host system or the sensor can initiate the transmission of data packages. Only one pin is required allowing for extremely compact metal can designs. Since the component drains very little current through the internal ASIC, the disturbance to the heat sensitive pyro-electric material is minimized.

Low-Power DigiPyro

In addition to the digitization stage, the Low Power DigiPyro Series (PYx x5xx and PYx x9xx) also contain an internal band-pass filter as well as a motion detection unit. After power-up, the host system configures the sensor and waits for an interrupt signal by the sensor.

The host system can adjust, via band-pass properties, the threshold which the amplitude has to cross, define the number of threshold crossings, the window time and a dead time to suppress immediate re-triggering.



While the PYx x5xx feature lowest possible power consumption with one PIR channel, PYx x9xx Series have two separately configurable PIR motion detection channels. This allows for differential signal analysis and improved signal-to-noise performance.

The optimal choice of parameters depends on the application and the selected lens. To determine those, the raw data can be accessed and analyzed.

The low power DigiPyro series are the optimal choice for battery-operated systems since the host system can be put to sleep while the sensor is continuously monitoring motion of people.

PYD 1788 • PYD 1798

Dual-Element DigiPyro®

This series represents DigiPyro in standard Dual-Element TO-5 housing with different window sizes. Both the PYD 1788 and PYD 1798 models include a built-in temperature reference. The output signals are communicated in one digital bit stream of 2x14 bit, output via a single wire "Direct Link" connection to a suitable host microprocessor.

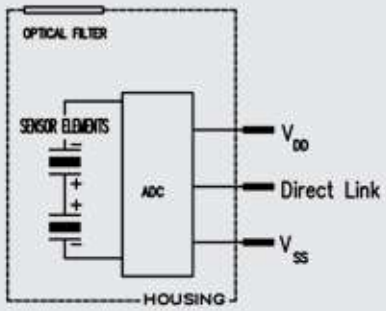
The DigiPyro PYD 1788 is the economy version with standard size window, while PYD 1798 features a larger filter window offering wider fields-of-view.

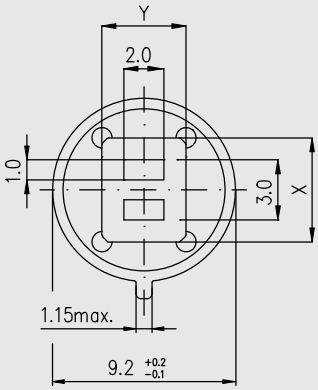
Features and Benefits

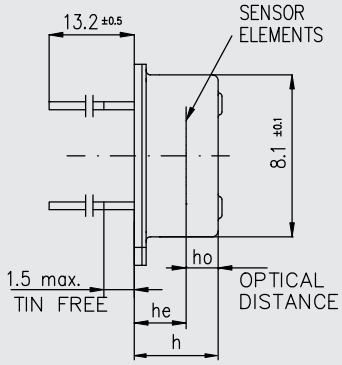
- TO-5 metal housing
- Digital direct link
- Different window sizes
- Excellent EMI protection

Target applications

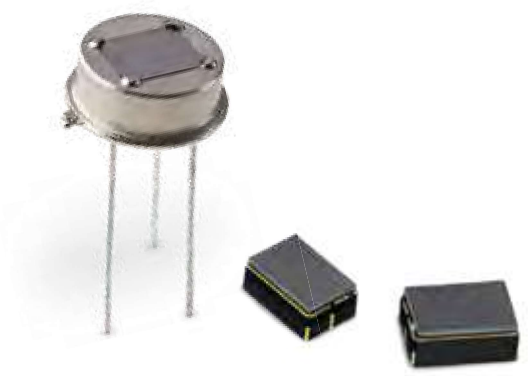
- Passive intrusion alarm
- Auto light switch
- Auto lamps







PYD 1788 - PYD 1798					
Parameter	**Symbol**	**PYD 1788**	**PYD 1798**	**Unit**	**Remarks**
Responsivity, min.	R_{min}	3.3	3.3	kV/W	f = 1 Hz
Responsivity, typ.	R	4.0	4.0	kV/W	f = 1 Hz
Match, max.	M_{max}	10	10	%	
Noise, max.	N_{max}	78	78	μV_{pp}	0.4...10Hz/20°C
Noise, typ.	N	20	20	μV_{pp}	0.4...10Hz/20°C
Operating Voltage		1.8...3.6	1.8...3.6	V	
Supply Current	I_{DDmax}	7	7	µA	V_{DD} = 3.3V, no load
Field of View, horizontal	FoV	100	120	◦	unobstructed, typ.
Field of View, vertical		90	120	°	unobstructed, typ.
Filter Size	X/Y	4.6 / 3.4	5.2 / 4.2	mm	
ADC Data					
Resolution		14	14	bit	typ.
Sensitivity		6.5	6.5	µV/count	typ.
Offset		8192	8192	bitcount	typ.
Optical Element Location	he/ho	3.1/0.7	3.1/0.7	mm	ho=optical
Housing height	h	4.2	4.2	mm	



PYD 1794 • PYD 2792

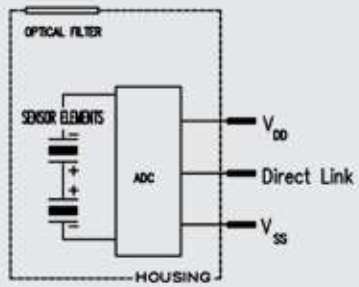
Dual-Element DigiPyro®

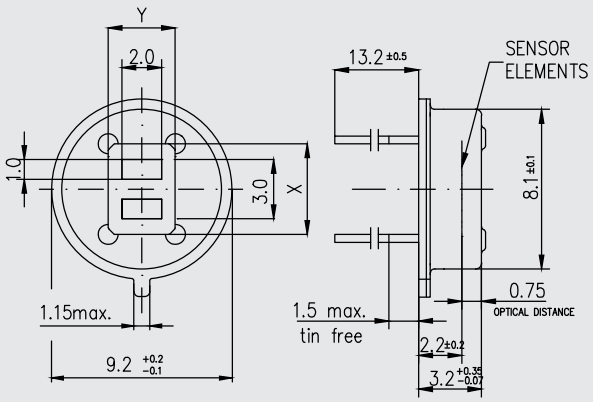
PYD 1794 DigiPyro represents the low-profile TO-39 housing version of standard DigiPyro. The output signal includes an internal temperature reference diode and is communicated in one digital bit stream of 2x14 bit, output via a single wire "Direct Link" connection to a suitable host microprocessor.

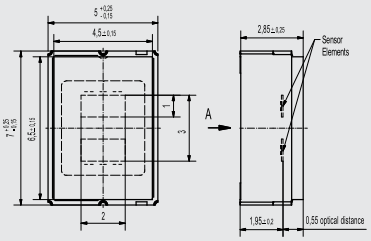
The DigiPyro PYD 2792 represents the new SMD version of this design, equipped with the standard Dual Element configuration. It is provided in Excelitas' new 5x7 low profile SMD housing.

Features and Benefits

- TO-39 & SMD housing options
- Digital direct link
- Excellent EMI protection
- Suited for passive intrusion alarm and all types of motion-activated devices







PYD 1794 - PYD 2792					
Parameter	**Symbol**	**PYD 1794**	**PYD 2792**	**Unit**	**Remarks**
Responsivity, min.	R_{min}	3.3	3	kV/W	f = 1 Hz
Responsivity, typ.	R	4.0	3.7	kV/W	f = 1 Hz
Match, max.	M_{max}	10	10	%	
Noise, max.	N_{max}	78	90	μV_{pp}	0.4…10Hz/20°C
Noise, typ.	N	20	30	μV_{pp}	0.4…10Hz/20°C
Operating Voltage		1.8…3.6	1.8…3.6	V	
Supply Current	I_{DDmax}	7	7	µA	V_{DD} = 3.3V, no load
Field of View, horizontal	FoV	115	147	°	unobstructed, typ.
Field of View, vertical		115	130	°	unobstructed, typ.
Filter Size	X/Y	5.2 / 4.2	5.5 / 3.7	mm	
ADC Data					
Resolution		14	14	bit	typ.
Sensitivity		6.5	6.5	µV/count	typ.
Offset		8192	8192	bitcount	typ.

PYD 1588 • PYD 1598 • PYD 2592

Dual-Element, Low-Power DigiPyro®

This series is designed with the utmost features of a digital Dual Element Pyro. In TO-5 housing this family is offered with two different window sizes. With its significant reduction of current requirements, this family provides wide range of operation voltage from 1.8V to 3.3V supply at a low current consumption in all operation modes.

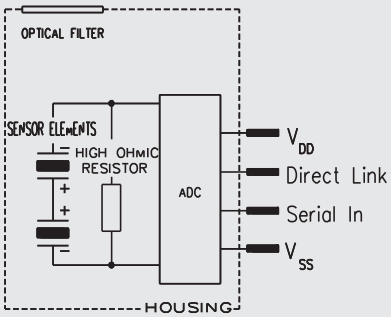
The internal electronic circuitry of PYD 1588 and PYD1598 enable the user to select and set individual functions. The output signals are communicated in one digital bit stream of 14 bit via a single wire "Direct Link" connection to a suitable host microprocessor. A similar single wire connection with separate input pin allows the settings of functional parameters such as sensitivity, bandpass selection, pulse count and wake up function. This Pyro provides the full functionality of a complete PIR sensing device when all following circuitry is in sleep mode.

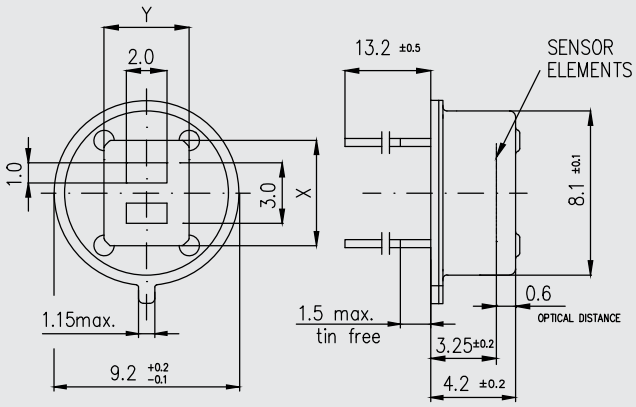
The DigiPyro PYD 1588 is provided with standard size window, while PYD 1598 with its larger filter window offers better White-Light-Immunity (WLI) performance and Field of View.

The DigiPyro PYD 2592 represents the new SMD version of this design, equipped with the standard Dual Element configuration. It is provided in Excelitas' new 5x7 low profile SMD housing. (Refer to SMD package drawing on page 16.)

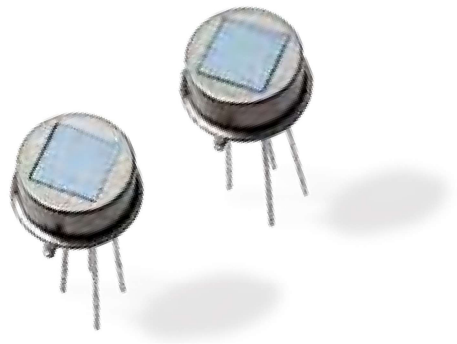
Features and Benefits

- Wake up/Sleep operation
- Sensitivity setting
- Bandpass selection
- Window time
- Digital Direct Link
- Ideal for battery operated devices





PYD 1588 - PYD 1598 - PYD 2592						
Parameter	**Symbol**	**PYD 1588**	**PYD 1598**	**PYD 2592**	**Unit**	**Remarks**
Responsivity, min.	R_{min}	3.3	3.3	3.0	kV/W	f = 1 Hz
Responsivity, typ.	R	4.0	4.0	3.7	kV/W	f = 1 Hz
Match, max.	M_{max}	10	10	10	%	
Noise, max.	N_{max}	78	78	90	μV_{pp}	0.4...10Hz/20°C
Noise, typ.	N	20	20	30	μV_{pp}	0.4...10Hz/20°C
Operating Voltage		1.8...3.6	1.8...3.6	1.8...3.6	V	
Supply Current	I_{DDmax}	3.5	3.5	3.5	µA	V_{DD} = 3.3V, no load
Field of View, horizontal	FoV	115	130	147	◦	unobstructed, typ.
Field of View, vertical		107	130	130	°	unobstructed, typ.
Filter Size	X/Y	4.6 / 3.4	5.2 / 4.2	5.5 / 3.7	mm	
ADC Data						
Resolution		14	14	14	bit	typ.
Sensitivity		6.5	6.5	6.5	µV/count	typ.
Offset		8000	8000	8000	bitcount	typ.



PYQ 1548

Quad-Element Low Power DigiPyro®

This Quad-Element DigiPyro configures all four elements combined to one output with exceptional energy-efficiency. The user selects and sets individual functions. A single-wire connection with separate input pin allows setting of sensitivity, bandpass selection, pulse count and wake up. This provides full functionality of a complete PIR sensing device when all following circuitry is in sleep mode.

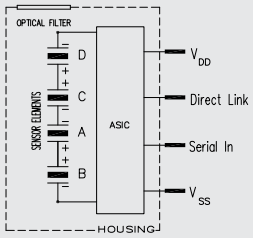
PYQ 1748

Quad-Element DigiPyro®

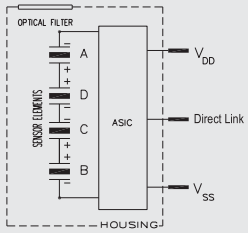
This DigiPyro provides economical Quad configuration with all four elements combined to one common output. This enables ceiling-mount applications when applied with suitable lens optics. TO-5 housing is provided with rectangular window to accommodate wider field-of-view. Standard geometrical element layout offers equal distance and spacing with cross polarity.

Features and Benefits

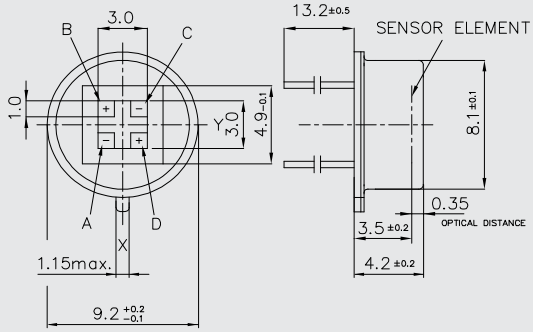
- TO-5 metal housing
- Equal element spacing
- Digital output via direct link
- Designed for ceiling-mount applications



PYQ 1548 Electrical



PYQ 1748 Electrical



PYQ 1548 Housing and PYQ 1748 Housing

PYQ 1548 - PYQ 1748					
Parameter	**Symbol**	**PYQ 1748**	**PYQ 1548**	**Unit**	**Remarks**
Responsivity, min.	R_{min}	5.4	5.4	kV/W	f = 1 Hz
Responsivity, typ.	R	6.5	6.5	kV/W	f = 1 Hz
Match, max.	M_{max}	10	10	%	
Noise, max.	N_{max}	140	140	μV_{pp}	0.4…10Hz/20°C
Noise, typ.	N	30	30	μV_{pp}	0.4…10Hz/20°C
Operating Voltage		1.8…3.6	1.8…3.6	V	
Supply Current	I_{DDmax}	7	7	µA	V_{DD} = 3.3V, no load
Field of View, horizontal	FoV	148	124	◦	unobstructed, typ.
Field of View, vertical		148	124	°	unobstructed, typ.
Filter Size	X/Y	4.9 / 4.9	4.9 / 4.9	mm	
ADC Data					
Resolution		14	15	bit	typ.
Sensitivity		6.5	6.5	µV/count	typ.
Offset		8192	8000	bitcount	typ.

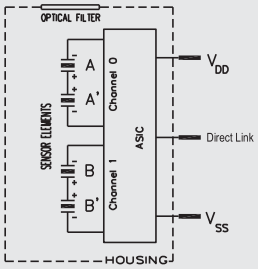
PYQ 2898 • PYQ 5848

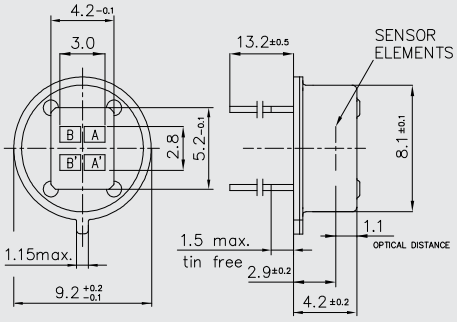
Quad-Element DigiPyro®

This Detector family is distinguished by two pairs of sensing elements with digitized signals for each pair. Together with the signal of an internal reference diode, the output via digital link forms a 3x14 bit stream. As to the spacing of the sensing elements, various designs are available. The TO-5 housing is provided with suitable window size to accommodate the field-of-view of the element configuration.

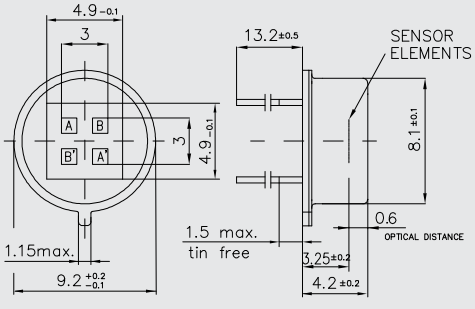
Features and Benefits

- TO-5 metal housing
- Dual-channel output
- Square / rectangular window
- Different element configuration options
- Suitable for wall and ceiling mount applications





PYQ 2898 Housing



PYQ 5848 Housing

PYQ 2898 - PYQ 5848					
Parameter	**Symbol**	**PYQ 2898**	**PYQ 5848**	**Unit**	**Remarks**
Responsivity, min.	R_{min}	3.5	6.0	kV/W	f = 1 Hz
Responsivity, typ.	R	4.5	8.0	kV/W	f = 1 Hz
Match, max.	M_{max}	10	10	%	
Noise, max.	N_{max}	80	100	μV_{pp}	0.4…10Hz/20°C
Noise, typ.	N	30	40	μV_{pp}	0.4…10Hz/20°C
Operating Voltage		2.7…3.6	2.7…3.6	V	
Supply Current	I_{DDmax}	15	15	µA	V_{DD} = 3.3V, no load
Field of View, horizontal	FoV	100	124	◦	unobstructed, typ.
Field of View, vertical		60	124	°	unobstructed, typ.
Filter Size	X/Y	5.2 / 4.2	4.9 / 4.9	mm	
ADC Data					
Resolution		14	14	bit	typ.
Sensitivity		6.5	6.5	µV/count	typ.
Offset		8192	8192	bitcount	typ.

Generally Applied IR Windows

Material used for filters and windows must be transparent in the wavelength of interest. Glass for example is generally not suited to sense the temperature of human skin since it absorbs wavelengths above 4µm. Common materials with a broad transmission range are Germanium and Silicon for the filter windows of IR Sensors. For outside protection only few materials are suitable. Among many plastics, only PP or HD-PE can be used as protection or as fresnel structured optics for presence and motion detection.

Detecting Gases

In the early days of the mining industry, the common method for gas detection was to take a bird in a cage along.

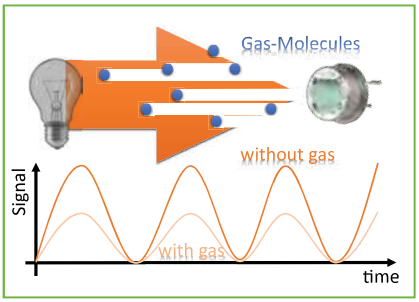
Canary birds were well known as an early warning system for toxic gases. If the bird went unconscious, it was high time to get out. Today electonic sensors have replaced the ancient system.

The now applied NDIR principle requires a combination of Thermal Radiation Source and Infrared Sensor. The selection of source strongly depends on spectral range. For range below 5m popular incandescent miniature lamps can be applied, for long-range thermal sources are required.

When designing NDIR-based gas sensors the selction of available Detectors is split between Pyrodetectors and Thermopile Sensors. Since NDIR usually applies modulated sources to prevent overheating, the engineer has the choice of preference. Both sensor priciples can be called equally suitable when fit with the narrow band window necessary for the speciffic gas absorption.

Special Application Detectors for Gas Sensing

Environmental protection is one of our most serious concerns. Features and instrumentation are required to measure and monitor all kinds of gas in

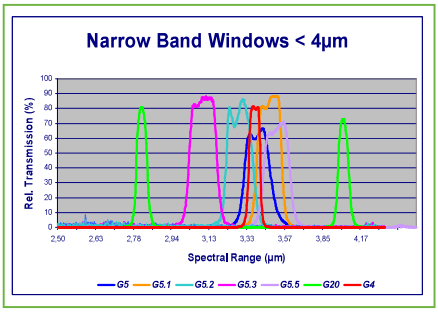


our environment. One of the methods applied is the NDIR technique, a principle of measuring gas concentration by its absorption properties in the infrared range.

Filters for Gas Sensors

The spectral sensitive range of the detectors is defined by a filter window. Common applications in infrared reference wavelengths from 2 to 20 µm. Long-range pyrometers apply a sharp cut-on/cut-off window of 9-14µm (G9) .

Excelitas offers single-channel detectors with such windows as well as Dual-Channel Detectors. When choosing Dual-Channel, typically one channel works as reference fit with a window that will have

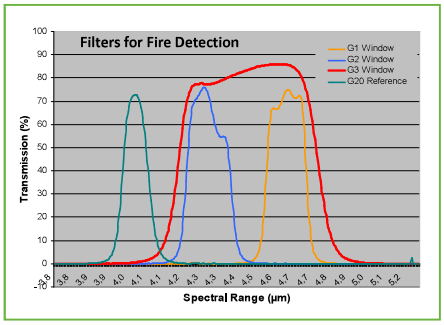


no gas absorption band (G20).
For sensing one specific gas by infrared absorption we offer narrow-band filters to detect specific gas absorption lines. The appropriate narrow band optical filters enable detection of Carbon Monoxide, Carbon Dioxide, Natural Gas and other environmental gases, as well as some technical gases. Please see the range of available filters and specifications.

Fire Detection

Since the exhaust of fire is mainly a hot emission of CO and CO_2, the infrared sensor may also be used for fire detection when fit with a suitable filter.

Our Detectors are applied in single- or dual-channel configurations. With the suited specific narrow-band spectral window our detectors and sensors are a vital part of making our environment more safe, secure and healthy.



Narrow Bands Filter Table

Filter type	Application	CWL	HPB
G1	CO	4.64µm	180nm
G2	CO_2	4.26µm	180nm
G2.2	CO_2	4.43µm	60nm
G2.5	CO_2	4,33µm	160 nm
G2.6	N_2O	4.53µm	85nm
G3	CO+CO_2	4.48µm	620nm
G4	NO	5.3µm	180nm
G5	HC	3.35µm-3,4µm	190nm
G5.1	HC	3.46µm	163nm
G5.2	HC	3,28-3,31µm	160nm
G5.3	HC	3.09µm	160nm
G5.5	HC	3,32-3,34µm	160nm
G5.6	HC	3.42µm-3,451µm	160nm
G5.7	HC	3,30-3,32µm	160nm
G5.9	HC	3.375µm-3,4µm	190nm
G7.1	R12	11.3µm	200nm
G7.2	R134a	10.27µm	210nm
G7.3		12.4µm	180nm
G20	Reference	3,95µm	90nm

PYS 3198TC

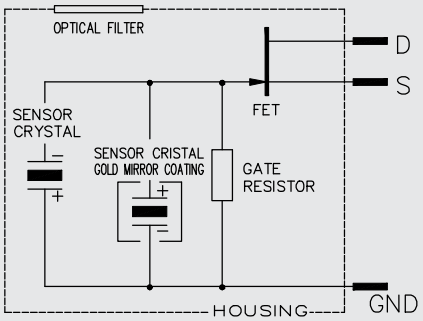
Single-Element Pyrodetector

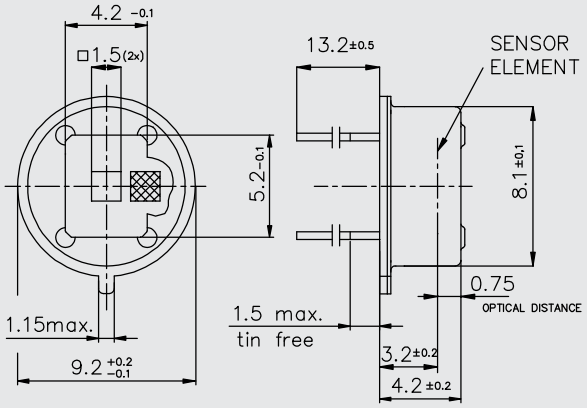
As Single-Element types we reference designs which combine one sensing element with a suited optical window. This makes single-Element types suitable for measurement applications.

One sensing element is placed in the center of the detector. For thermal compensation an additional element which is blinded from radiation is connected in parallel. The TO-5 Metal Housing is equipped with an optical filter window. For gas measuring applications the spectral range is narrowed to match the gas absorption in IR range. As such the detector window suites as spectral narrow band filter. Various configurations are available for detection of more common gasses.

Features and Benefits

- TO-5 metal housing
- Different spectral filters available
- Suited for gas monitoring





PSY 3198TC				
Parameter	**Symbol**	**PYS 3198TC**	**Unit**	**Remarks**
Responsivity, min.	R_{min}	2.2	kV/W	f = 1 Hz
Responsivity, typ.	R	3.5	kV/W	f = 1 Hz
Noise, max.	N_{max}	50	μV_{pp}	0,4…10Hz/20°C
Noise, typ.	N	15	μV_{pp}	0,4…10Hz/20°C
spec. Detectivity	D*	17	10^7cm*√Hz/W	1Hz/ 1Hz BW
Field of View, horizontal	FoV	135	°	unobstructed
Field of View, vertical		122	°	unobstructed
Source Voltage		0,2…1,5	V	47 kΩ, 20°C
Operation Voltage	V_{DD}	2-10	V	unobstructed

PYS 3398TC

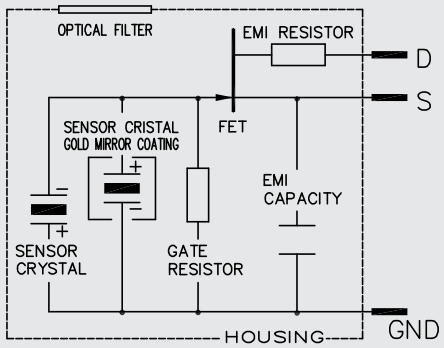
Single-Element Pyrodetector

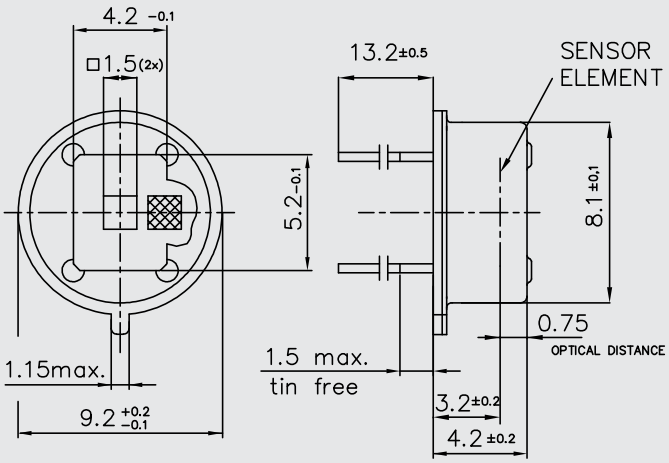
This Single-Element Pyrodetector combines one sensing element with a suited optical window. This makes single-element types suitable for measurement applications. This version of Single-Element Detector is especially resistant to EMI by means of drain resistor and source capacitor.

One sensing element is placed in the center of the detector. For thermal compensation an additional element which is blinded from radiation is connected in parallel. The TO-5 metal housing is equipped with an optical filter window. For gas measuring applications the spectral range is narrowed to match the gas absorption in IR range. As such the detector window suits as spectral narrow-band filter. Various configurations are available for detection of more common gasses.

Features and Benefits

- TO-5 metal housing
- Different spectral filters available
- EMI protection
- Suited for gas monitoring





PSY 3398TC				
Parameter	**Symbol**	**PYS 3398TC**	**Unit**	**Remarks**
Responsivity, min.	R_{min}	2.2	kV/W	f = 1 Hz
Responsivity, typ.	R	3.5	kV/W	f = 1 Hz
Noise, max.	N_{max}	50	μV_{pp}	0,4…10Hz/20°C
Noise, typ.	N	15	μV_{pp}	0,4…10Hz/20°C
spec. Detectivity	D*	17	10^7cm*√Hz/W	1Hz/ 1Hz BW
Field of View, horizontal	FoV	135	°	unobstructed
Field of View, vertical		122	°	unobstructed
Source Voltage		0,2…1,5	V	47 kΩ, 20°C
Operation Voltage	V_{DD}	2-10	V	unobstructed

PYS 3428TC

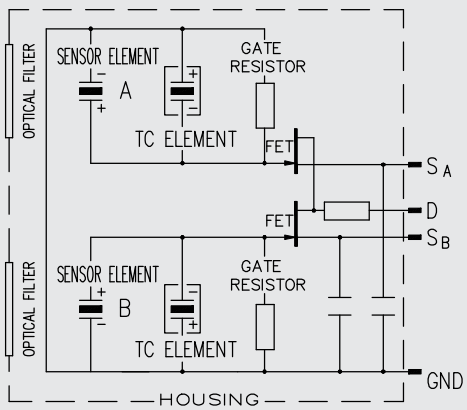
Dual-Channel Pyrodetector

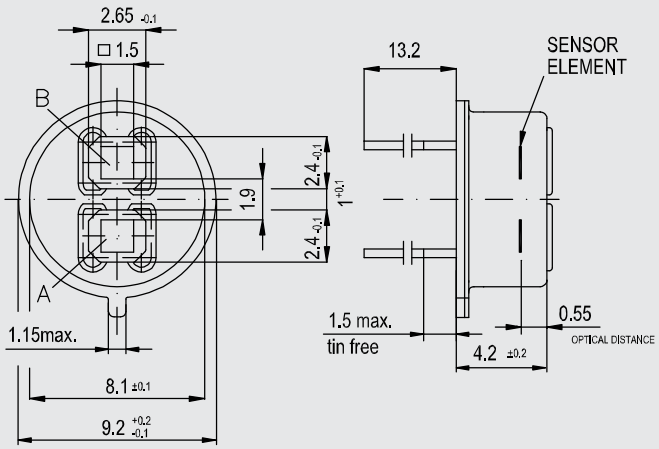
This Single-Element, Dual-Channel Pyrodetector includes two single elements thermally compensated. Each output is optically associated with its own optical window within the TO-5 metal housing. They form individual output signals, thus the name "Dual-Channel".

For gas measuring applications the spectral range is narrowed to match the gas absorption in IR range. Usually one channel is used as reference channel suited with a bandwidth which shows no gas absorption. The second channel serves as the gas sensing output. Various filter selections are available to detect the most prominent gasses.

Features and Benefits

- TO-5 metal housing
- Different spectral filters available
- EMI protection
- Suited for gas monitoring





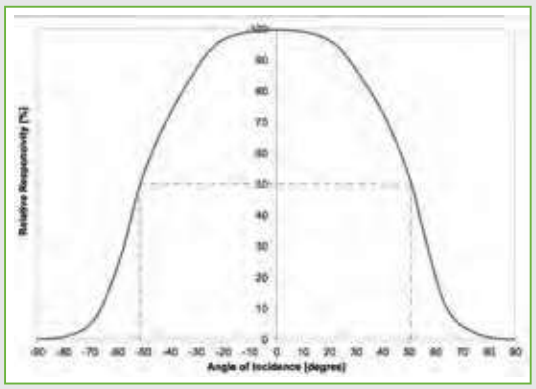
PYS 3428TC				
Parameter	**Symbol**	**PYS 3428TC**	**Unit**	**Remarks**
Responsivity, min.	R_{min}	2.2	kV/W	f = 1 Hz
Responsivity, typ.	R	3.5	kV/W	f = 1 Hz
Noise, max.	N_{max}	50	μV_{pp}	0,4…10Hz/20°C
Noise, typ.	N	15	μV_{pp}	0,4…10Hz/20°C
spec. Detectivity	D*	17	10^7cm*√Hz/W	1Hz/ 1Hz BW
Field of View, horizontal	FoV	77	°	unobstructed
Field of View, vertical		77	°	unobstructed
Source Voltage		0,2…1,5	V	47 kΩ, 20°C
Operation Voltage	V_{DD}	2-10	V	unobstructed

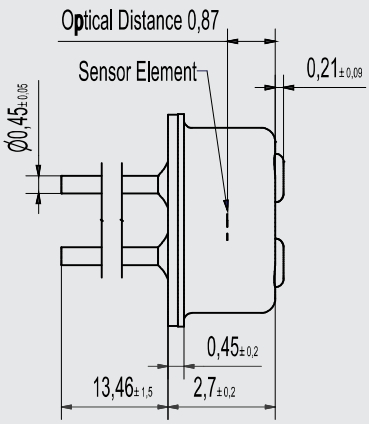
TPD 1T 0623 • TPD 1T 0823

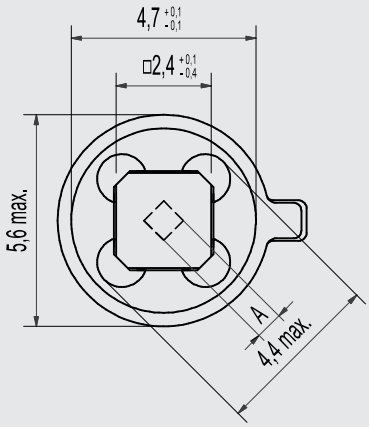
High-Sensitivity Thermopile Detectors

This Thermopile Detector series offered in TO-46 housing with square size window is specially designed for high output signal level. It is equipped with internal Thermistor serving as temperature reference for Thermopile temperature compensation. With the square window size offering wide field of view and the option to select narrow bad filters G1…G5 as per page 36 of this brochure it is the best choice for Gas sensing applications.

The TPD1T 0823 is a special version for fast response when needed in gas sensing applications.







TPD 1T 0623, TPD 1T 0823

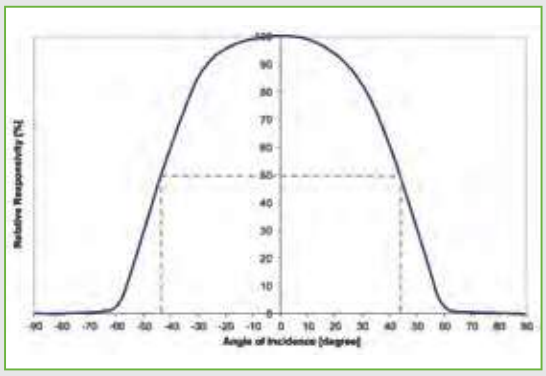
Parameter	Symbol	TPD 1T 0623	TPD 1T 0823	Unit	Remarks
Sensitive Area	A	1.2 x 1.2	1.2 x 1.2	mm	Absorber Area
Thermopile Resistance	R_{TP}	50…110	70…120	kΩ	25°C
Responsivity	R	33	32	V/W	500°K / 1Hz / Without IR-filter
Sensitivity (Tdet 25 °C / Tobj 40 °C)	S_{40}	133	124	µV/K	With standard filter (LWP, cut-on 5.5 µm)
Sensitivity (Tdet 25 °C / Tobj 100 °C)	S_{100}	177	165	µV/K	With standard filter (LWP, cut-on 5.5 µm)
Time Constant	t	27	10	ms	
Noise Voltage	V_n	36	38	nV/√Hz	25°C
Specific Detectivity	D*	1.1	1.1	10^8 cm√Hz/W	25°C
Temp. Coefficient of Resistance	TC_{RTP}	0,03	0,03	%/K	
Temp. Coefficient of Responsivity	T_{CR}	-0,05	-0,05	%/K	
Field of view	FoV	104	104	Degrees	at 50% intensity points
Thermistor resistance (25°C)	R_{25}	100	100	kΩ	25 °C
Thermistor BETA-value	β	3964	3964	K	defined at 25 °C / 100 °C

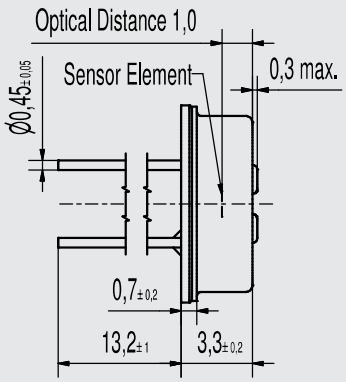
TPD 2T 0625 • TPD 2T 0825

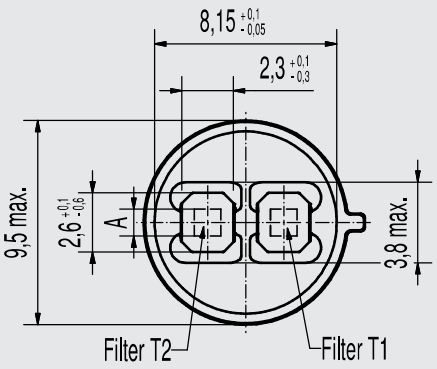
High-Sensitivity Thermopile Detectors

This specially designed Detector offers Dual-Channel performance in a TO-39 housing with two individual optical windows. Typically one window is fitted with a reference filter G20, while the other window is fitted with a narrow-band pass filter selected for a specific gas, see page 36 of this brochure for available selection. It also includes the internal Thermistor as temperature reference for Thermopile temperature compensation.

The TPD 2T 0825 is a special version for fast response when needed in critical gas sensing applications.







TPD 2T 0625, TPD 2T 0825

Parameter	Symbol	TPD 2T 0625	TPD 2T 0825	Unit	Remarks
Sensitive Area	A	1.2 x 1.2	1.2 x 1.2	mm	Absorber Area
Thermopile Resistance	R_{TP}	50…110	70…120	kΩ	25°C
Responsivity	R	33	32	V/W	500°K / 1Hz / Without IR-filter
Sensitivity (Tdet 25 °C / Tobj 40 °C)	S_{40}	115	112	µV/K	With standard filter (LWP, cut-on 5.5 µm)
Sensitivity (Tdet 25 °C / Tobj 100 °C)	S_{100}	155	151	µV/K	With standard filter (LWP, cut-on 5.5 µm)
Time Constant	t	27	10	ms	
Noise Voltage	V_n	36	38	nV/√Hz	25°C
Specific Detectivity	D*	1.1	1.1	10^8 cm√Hz/W	25°C
Temp. Coefficient of Resistance	TC_{RTP}	0,03	0,03	%/K	
Temp. Coefficient of Responsivity	T_{CR}	-0,05	-0,05	%/K	
Field of view	FoV	87	87	Degrees	at 50% intensity points
Thermistor resistance (25°C)	R_{25}	100	100	kΩ	25 °C
Thermistor BETA-value	β	3964	3964	K	defined at 25 °C / 100 °C

Handling

Infrared Sensors are Optical devices and require careful handling in production. As to mechanical recommendations:

- Avoid dropping the devices on the production flow.
- Avoid physical force to detector leads, do not bend leads unless necessary.
- Ensure leads are not damaged when manipulating them.

Electrostatic discharges may destroy the detectors. It is recommended to apply the standard precautions for ESD sensitive devices to prevent potential damage.

The detector windows are optical filters with multi-layer coatings.

- Avoid touching the detector window. To clean windows, use only ethyl alcohol with a cotton swab.
- Do not expose Detectors to chemical fluids such as Freon, Trichloroethylene and other aggressive detergents.

Environmental Conditions

With the construction of metal can and spectral window inserted into the can by a special durable epoxy, the detectors are sealed and tested for long-term enclosure. The detector will pass He-leakage test with maximum leakage rate specification of $5x10^{-8}$ mbar ls-1. Detectors shall not increase noise or change responsivity when exposed to maximum of 95% relative humidity at 30°C.

- Avoid long-term storage at high humidity with high temperatures.

As IR detectors are optical sensors, avoid condensation effects on the detector. Operation below dew points may affect the performance.

Reliability Standards

Excelitas' continuous reliability qualification and monitoring program ensures that all outgoing products meet quality and reliability standards. Tests are performed according to approved semiconductor device standards, such as IEC, MIL, and JDEC (see table). For detailed information please contact Excelitas.

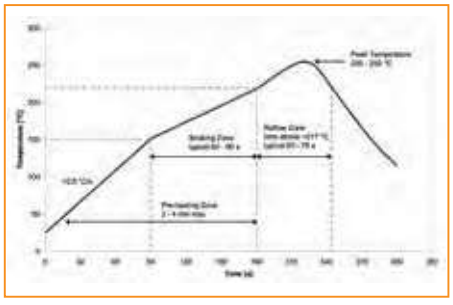
Quality and Reliability Standards

Excelitas strives to meet applicable quality and reliability standards. We are certified ISO 9001:2015 and operate at established SPC and TQM. We are proud to operate under Environmental Management System according to ISO 14001:2015 and the Occupational Safety and Health Management System according to OHSAS 18001: 2007.

All devices employing PCB assemblies are manufactured according IPC-A-610 class 2 guidelines.

Excelitas Thermal Infrared Sensor product line is certified for ANSI/ESD S.20.20:2014.

In case of questions please feel free to contact us for the latest update on our current certificates and forms. Our continuous qualification and reliability program ensures that all products meet the specified performance criteria.



As to outgoing inspection, all devices have to pass 100% testing of major parameters and gross leak in acc. to MiL Std. 883 m 1014C1. Due to high-volume production individual data are not protocolled or stored, statistical data are kept for reference.

Soldering of SMD Devices

The TPiD 1S and TPiS 1S series are lead-free components and fully comply with the RoHS regulations, especially with existing roadmaps of lead-free soldering. Reflow soldering is recommended. A typical lead free reflow profile is shown in figure 4. Specific reflow soldering parameters depend on the solder alloy used.

The device meets MSL1 at 245 °C according to JEDEC standard.

Soldering Conditions

For the soldering of the detectors within PCBs, the typically applied and recommended process is wave soldering. During the automatic wave solder process we strongly advise to restrict preheating to avoid heat exposure through the detector window, if necessary apply a protection cap. When the detector is directly exposed to the radiation of such heaters the detector shall be protected from that heat. Manual soldering is also possible when maintaining similar temperature profiles.

Reflow soldering is not possible for TO housing versions of our detectors. For our range of SMD housing detectors please reference the recommended solder profile.

Pyro Detectors

Pyro Detectors	Analog /Digital	TO5	TO39	SMD	Wall Mount	Ceiling Mount	Gas Monitor	Supply
Dual Element Detectors								
PYD 1398	A1	X			X			2-10V
PYD 1388	A1	X			X			2-10V
PYD 1378	A1	X			X			2-10V
PYD 1798	D1	X			X			3.0V
PYD 1798	D1	X			X			1.8V
PYD 1788	D1	X			X			3.0V
PYD 1598	D1	X			X			1.8V
PYD 1588	D1	X			X			1.8V
PYD 2592	D1			X	X			1.8V
PYD 1794	D1		X		X			3.0V
PYD 2792	D1			X	X			1.8V
Quad Element Detectors								
PYQ 2498	A2	X			X			2-10V
PYQ 1398	A1	X				X		2-10V
PYQ 5448	A2	X				X		2-10V
PYQ 1348	A1	X				X		2-10V
PYQ 1748	D1	X				X		3.0V
PYQ 1548	D1	X				X		1.8V
PYQ 5848	D2	X				X		3.0V
PYQ 2898	D2	X			X			3.0V
Gas Detectors								
PYS 3198	A1						X	2-10V
PYS 3398	A1						X	2-10V
PYS 3428	A2						X	2-10V

Thermopile Detectors

Thermopile Detectors and Sensors	Analog / Digital	TO5	TO39	TO46	SMD	Temp Monitor	Gas Monitor	Presence Detection
TPD 1T 0122 L3.0	A			X		X		
TPD 1T 0122	A			X		X		
TPD 1T 0223	A			X		X		
TPiD 1T 0224	A		X			X		
TPiD 1T 0624	A		X			X		
TPD 1T 0226 IRA	A	X				X		
TPiD 1T 0226 L5.5	A	X				X		
TPiD 1T 0122B	A			X		X		
TPiD 1T 0222B	A			X		X		
TPiD 1T 0622B	A			X		X		
TPiD 1S 0121	A				X	X		
TPiD 1S 0222	A				X	X		
TPiS 1S 1051	D				X	X		
TPiS 1S 1252	D				X	X		
TPiS 1T 1252B	D			X		X		
TPiS 1T 1254	D		X			X		
TPiS 1T 1256 L5.5	D	X				X		
TPiS 1S 1385	D				X			X
TPiS 1S 0185	D				X			X
TPiS 1T 1086 L5.5	D	X				X		
TPiS 1T 0186 L5.5	D	X				X		
TPiS 1T 1084	D		X			X		
TPM 1T 0134 M	A		X			X		
TPiM 1T 0136 L5.5	A	X				X		
TPD 1T 0623	A			X			X	
TPD 1T 0823	A			X			X	