DigiPile™

Infrared Sensing Solutions

TPiS 1T 1252B / 5058

Product Specification

Features

- TO-46 package
- Isothermal sensor housing
- High sensitivity thermopile with 84° field-of-view
- Integrated signal processing

Applications

- Remote temperature measurement
- In-ear thermometry
- Forehead thermometry
- Body temperature measurement

Compact Isothermal Thermopile

The TPiS 1T 1252B is a thermopile sensor with integrated digitization. It provides as a member of the DigiPile™family a proprietary low power 1-wire digital interface to access the raw data from any micro controller. It features a confined field of view in a TO-46 package.
The package features isothermal materials and constructions which ensure a quick thermal equilibrium along the sensor head.
The sensor is uncalibrated. The calibration after packaging into the final product enables highest accuracies like required for medical applications. Instructions for calibration procedures are provided if requested.
One typical application is in-ear thermometry or fever screening at the forehead.

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Contents

1 Dimensions and Connections

Figure 1: Mechanical Dimensions (in mm) and Pin Configuration. A short description is given in table 1. .

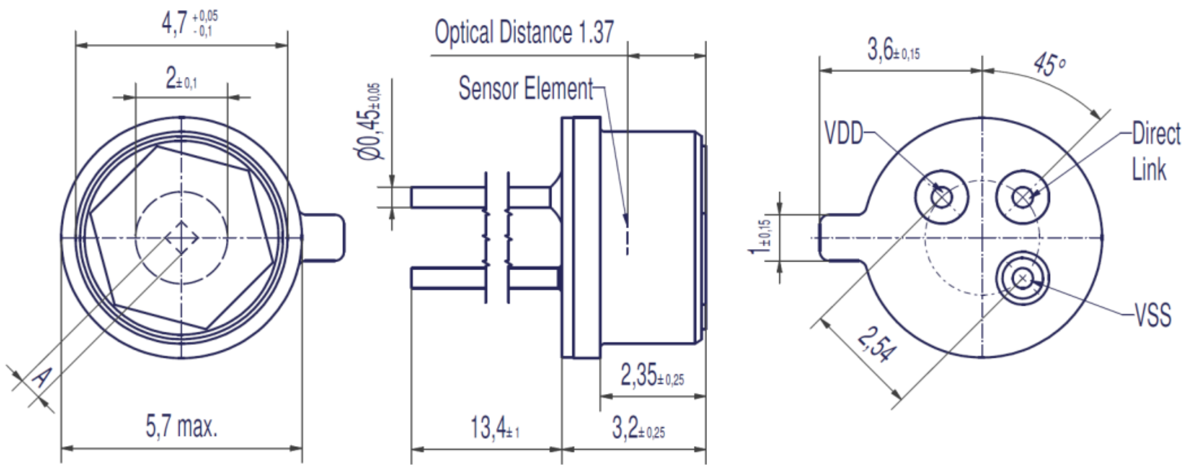

Table 1: Pin descriptions. Further explanations follow in this document.

Pin Symbol	Pin Name and short Functional Description.	Pin Type
DL	**Direct Link:** Proprietary 1-wire Interface. Pull-up resistors are not applicable.	Input / Output
VSS	**Ground**: The ground (GND) reference for the power supply should be set to the host ground.	Power
VDD	**Power Supply**: The power supply for the device. Typical operating voltage is 3.3 V	Power

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2 Optical Characteristics

2.1 Field of View

Figure 2 illustrates the measurement of the sensor's field of view (FOV). A hot point like heat source radiates almost parallel infrared light in a distance to the sensor. The sensor's housing is rotated around its sensor plane in all directions while recording the sensor data. A typical measurement result is shown in figure 3. The result is normalized to the peak value of the measurement. The resulting parameters are depicted in table 2.

Figure 2: Illustration of the FOV measurement setup. For details see the text.

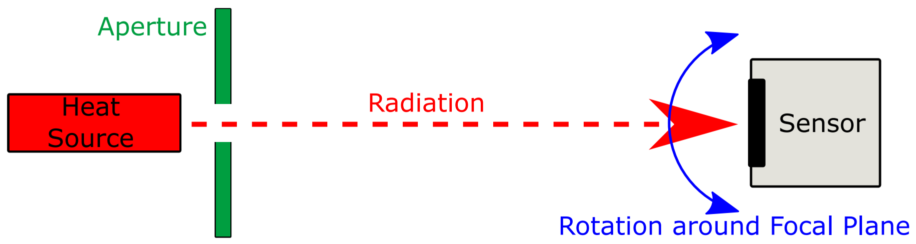

Figure 3: Typical FoV measurement result

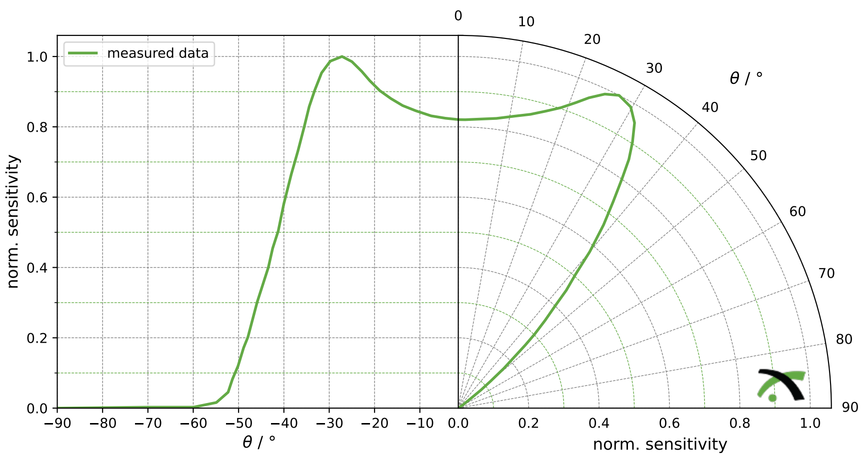

Table 2: Optical characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Remarks / Conditions
Field of View	FOV		84		°	at 50 % intensity
Optical Axis		−10	0	10	°	

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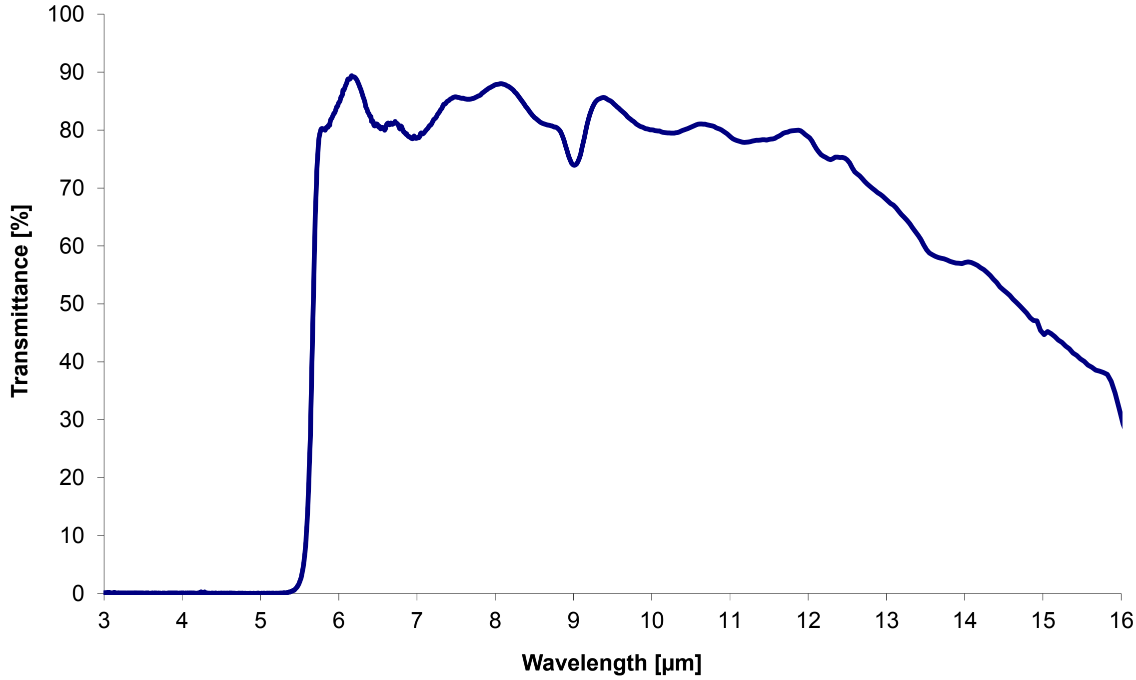
2.2 Filter Properties

Table 3: Filter properties

Parameter	Symbol	Min	Typ	Max	Unit	Remarks / Conditions
Average Filter Transmittance	T_A	75	>77		%	$7.5\,\mu m < \lambda < 13.5\,\mu m$
Average Filter Transmittance	T_A			<0.5	%	$\lambda < 5\,\mu m$
Cut-on Wavelength	$\lambda(5\,\%)$	5.2	5.5	5.8	µm	at 25 °C

Figure 4: Filter transmittance, typical curve



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3 Absolute Maximum Ratings

Table 4: Maximum Ratings

Parameter	Symbol	Min	Max	Unit	Remarks / Conditions
Operating Temperature	T_0	−20	70	°C	Electrical parameters may vary from specified values in accordance with their temperature dependence
Operating Humidity			95	% r.h.	Non condensing
Storage Temperature	T_s	−40	100	°C	Avoid storage in humid environment
Supply Voltage	VDD	−0.3	3.6	V	
Current to any pin		−100	100	mA	One pin at a time

Stresses beyond the limits listed in table 4 may cause permanent damage to the device. Exposure to absolute maximum ratings for long time may affect the device reliability and may lead to deterioration of any parameter.

4 Device Characteristics

Device characteristics are given at 25 °C ambient temperature unless stated otherwise.

Table 5: Power Supply

Parameter	Symbol	Min	Typ	Max	Unit	Remarks / Conditions
Operating Voltage	VDD	2.4	3.3	3.6	V	
Supply Current	IDD		8.5	10.5	µA	VDD=3.3 V

Table 6: Thermopile

Parameter	Symbol	Min	Typ	Max	Unit	Remarks / Conditions
Sensitive Area	A		0.26		mm^2	Absorber $0.51 \times 0.51\ mm^2$
Sensitivity	$\Delta counts/\Delta T$	240	290	350	counts/K	Tobj=40 °C
Noise(peak-peak)			8	28	counts	Tobj=40 °C
Time constant	τ		22		ms	Additional 8 Hz LP Filter
Power up time			250		ms	TP_{OBJ} and TP_{AMB} stable
Resolution			17		Bits	
Sensitivity		0.7	0.8	0.9	µV/count	
Offset		64 000	64 500	65 000	counts	
Max. Object Temp.	$Tobj_{max}$		160		°C	Full FOV, $\epsilon > 99\,\%$

The TPiS 1T 1252B temperature measurement is specified for a full field-of-view coverage by a black body with more than 99 % emissivity.
The calculation of a temperature has to be performed on the host system and is described in section 5.
Figure 5 shows the calculated thermopile raw data TP_{object} as a function of the ambient temperature and object temperature based on typical characteristics of TPiS 1T 1252B . The ASIC typically features a wider dynamic range as compared to the specified values in table 6 and 7. Values out of our specifications are not guaranteed.
The measurement of thermopile parameters is described in section 5. The performance in the application may vary due to physical constraints. Please consult our local representative for more information.

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Table 7: Ambient temperature sensor (PTAT)

Parameter	Symbol	Min	Typ	Max	Unit	Remarks / Conditions
Resolution			14		Bits	
Slope			90		counts/K	−20 °C to 85 °C
Range		−20		85	°C	
Linearity		−5		5	%	−20 °C to 85 °C
Offset		7000	8200	9400	counts	
Noise(peak-peak)			6	16	counts	Over period of 2 s.

Figure 5: Typical temperature dependence of the raw thermopile output

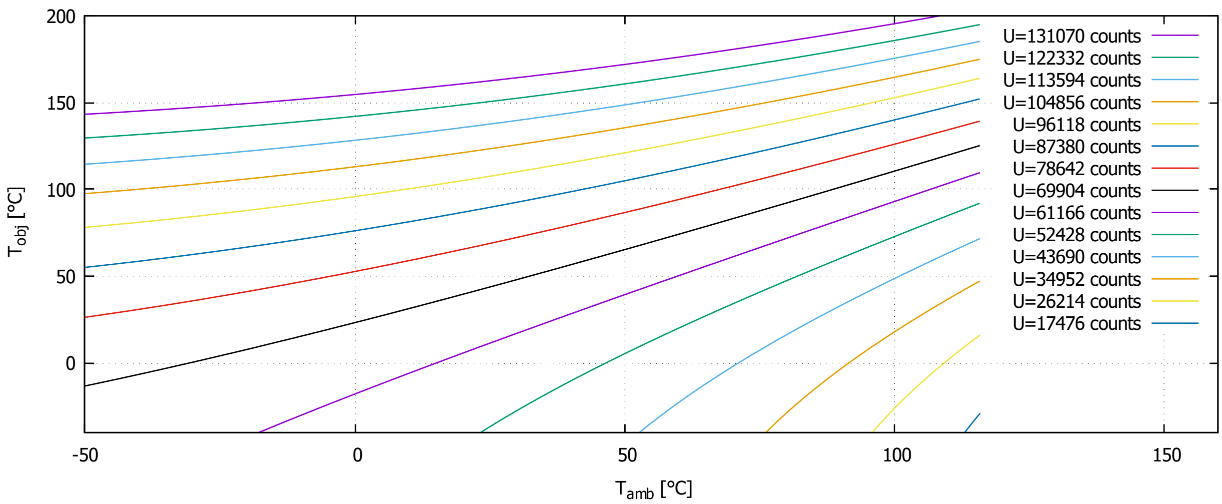

Table 8: Electrical Data. Unless specified differently all data refers to 25 ± 3 °C.

Parameter	Symbol	Min	Typ	Max	Unit	Remarks/Conditions
Direct Link						
Input Low Voltage	V_{IL}			$0.2V_{DD}$	V	
Input High Voltage	V_{IH}	$0.8V_{DD}$		$V_{DD} + 0.3$ V	V	
Input Current	I_I	−1		1	μA	
Data Setup Time	t_{DS}	90		200	μs	
Data Clock Low Time	t_{DL}	200		2000	ns	
Data Clock High Time	t_{DH}	200		2000	ns	
Data Bit Settling Time	t_{BS}			2	μs	C_{LOAD} < 10 pF
Sample Time	t_{SMPL}	3.0		14.6	ms	
Bit Time	t_{BIT}			25	μs	
Update Time	t_{UP}	70			μs	

Table 9: Sensors's ASIC oscillator properties

Parameter	Symbol	Min	Typ	Max	Unit	Remarks / Conditions
Frequency	F_{OSC}	60	70	80	kHz	
Temperature Dependence		−1000		1000	ppm/K	

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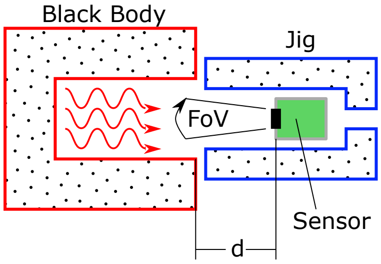
5 Temperature Measurement

The TPiS 1T 1252B is an uncalibrated sensor. This section discusses a possible calibration method and calibration conditions which were used to determine and specify the sensor properties.

5.1 Measurement Conditions

The thermopile output is related to the net IR-radiation. The net IR-radiation can be correlated with the object temperature for a specific fixed set-up. The set-up valid for the properties as specified is shown in sketch 6.

Figure 6: Measurement conditions



A silicon-oil immersed hollow black body with an inner diameter of 55 mm and an emissivity of better than 99 % has a temperature T_{obj} of 40 °C. A temperature controlled jig with a inner diameter of 35 mm has a temperature T_{amb} is at (25.0 ± 0.5) °C and is coated with a black paint for an emissivity of better than 96 %. The jig contains the TPiS 1T 1252B sensor at a distance of 0 mm to the black body.

Conditions other than described in this document will lead to different properties such as sensitivity and temperature range. Please contact our local representative for more details.

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5.2 Calculation of the Ambient Temprature

For a correct object temperature calculation the ambient temperature must be known. The temperature should be calculated in Kelvin and not °C. To calculate the ambient temperature out of $TP_{ambient}$ the following formula can be applied.

$$T_{\text{ambient}}[\text{K}] = (25 + 273.15) + (\text{TP}_{\text{ambient}} - \text{PTAT25}) \cdot (1/M)$$

using the calibration constants PTAT25 and M.
To calibrate the PTAT calibration constants, the sensor must be exposed to 2 different ambient temperatures $T_{ambient\ 1}$ [K] and $T_{ambient\ 2}$ [K] while reading the corresponding PTAT values $TP_{ambient\ 1}$ [counts] and $TP_{ambient\ 2}$ [counts]. We recommend an innert fluid bath. The calibration constants are calculated then by

$$\text{M} = \frac{(\text{TP}_{\text{ambient 2}} - \text{TP}_{\text{ambient 1}})}{(T_{\text{ambient 2}} - T_{\text{ambient 1}})}$$

and

$$\text{PTAT25} = \text{TP}_{\text{ambient 1}} + (25\,^{\circ}\text{C} - T_{\text{ambient 1}}[^{\circ}\text{C}]) \cdot M$$

The inverse to calculate an expected PTAT value for a given temperature T_{amb} is given by

$$\text{TP}_{\text{ambient}}[\text{counts}] = [T_{\text{amb}} - (25 + 273.15)] \cdot M + \text{PTAT25}$$

5.3 Calculation of the Object Temperature

The thermopile output signal TP_{object} is not only depending on the objects temperature but also on the ambient temperature $T_{ambient}$.To obtain the object temperature T_{object} calculate

$$T_{\text{object}}[\text{K}] = F\left[\frac{\text{TP}_{\text{object}} - \text{TP}_0}{k} + f(T_{\text{ambient}})\right]$$

where $T_{ambient}$ is obtained as discussed in section 5.2. k is a scaling/calibration factor given by

$$k = \frac{\text{TP}_{\text{object 1}} - \text{TP}_0}{f(T_{\text{object 1}}[\text{K}]) - f(T_{\text{ambient 1}}[\text{K}])}$$

and contains the emissivity ϵ of the object as well as the field-of-view coverage factor Θ. TP_0 is the thermopile offset. It is obtained when the object and ambient temperature are the same (thermal equilibrium). This is for example the case when calibrating the PTAT in an innert fluid. $TP_{object\ 1}$ is the thermopile output while pointing the sensor at a warm black body with a temperature $T_{object\ 1}$. The ambient temperature $T_{ambient\ 1}$ is the condition while calibrating the thermopile in front of the black body. It should be determined with the sensors PTAT.
$f(x)$ is in the simplest case an exponential with the exponent defined by the sensor type.

$$f(x) = x^{3.8}$$

It's reverse function $F(x)$ is then

$$F(x) = \sqrt[3.8]{x}$$

To predict a thermopile output based on the object temperature T_{object} and ambient temperature $T_{ambient}$ calculate

$$\text{TP}_{\text{object}}[\text{counts}] = k \cdot \left[f(T_{\text{object}}[\text{K}]) - f(T_{\text{ambient}}[\text{K}])\right] + \text{TP}_0$$

Since exponents and roots are heavy operations to be performed on a micro-controller based system, we recommend to implement $f(x)$ as a lookup table. An implementation in Object-C language can be provided upon request. You may contact our local representative for more details.

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6 Integration instructions and recommendations

6.1 Position

In order to obtain the highest possible performance it is possible to operate the sensor without a (protecting) front window. To measure an accurate temperature no window between the sensor and the object must be used. Excelitas measurement values are only valid when the bare sensor is exposed to the object.
As the device is equipped with a highly sensitive infra-red detector, it is sensitive to any source of heat, direct or indirect. For a proper temperature measurement the device must be at the same temperature as the ambient. Sudden temperature changes will directly affect the behaviour of the sensor's performance.
This device is equipped with a highly sensitive ADC and integrated circuits. Common rules of electronics integration apply. We recommend to place strong EMI sources far apart and/or to shield those.

6.2 Soldering

For the soldering of the detectors within PCBs, the typically applied and recommended process is wave soldering. The recommended soldering temperature shall not exceed 300 °C with a maximum exposure time of 5 s.
Other soldering processes are also possible when maintaining similar temperature profiles. Temperatures higher than recommended may affect its performance. Any soldering process should be qualified to avoid damage to the sensor.
For highest accuracy and best temperature compensation, it is recommended to keep a small gap (1 mm) between the PCB and sensor base plate.

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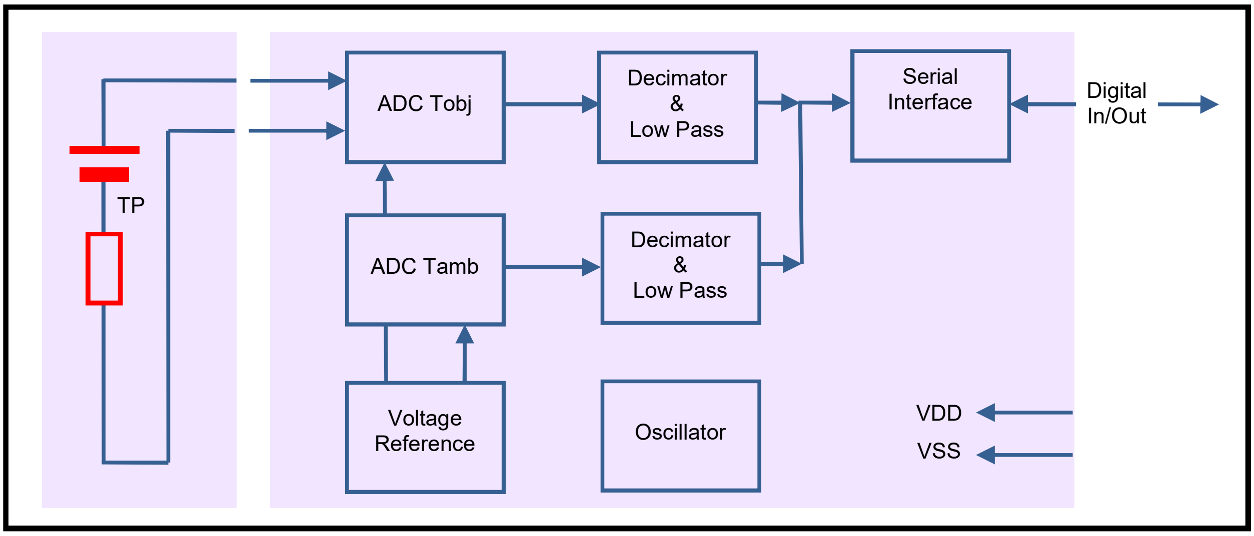
7 Interface Characteristics

7.1 Interface Overview

Figure 7: Block Diagram



The functional diagram 7 illustrates the functional blocks of the TPiS 1T 1252B . The thermopile sensing element, generates a voltage, which is proportional to the IR-net-radiation. It is connected to a built-in IC,
The thermopile voltage is digitized with a high resolution and high linearity differential analog-to-digital converter. The PTAT is a linear reference sensor temperature which is proportional to the temperature change. It is digitized with a separate ADC. Both channels are low pass filtered for optimal signal-to-noise performance.
The ASIC includes an on-chip oscillator and a voltage reference to make it independent from the voltage supply.
A proprietary serial interface called "DIRECT LINK" is used to read the digitized data.

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7.2 Direct Link Interface

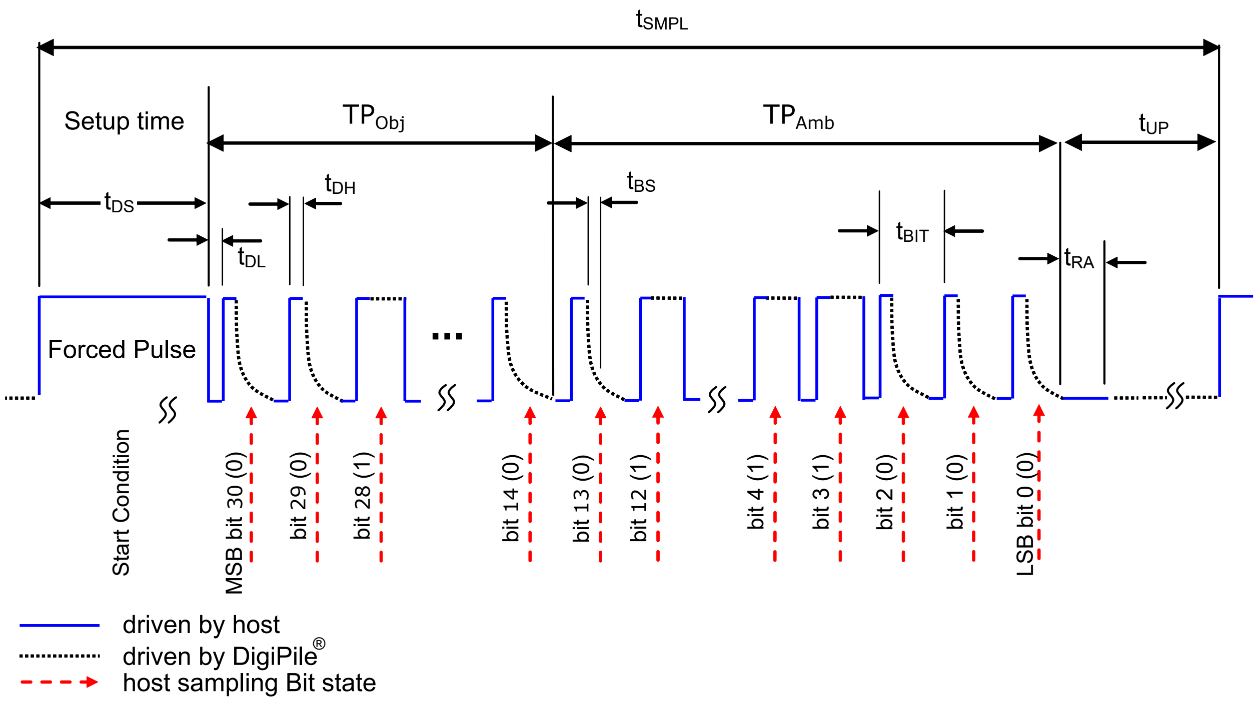
The DIRECT LINK interface is a bi-directional one wire serial interface which is used to continuously retrieve data from the sensor.

Table 10: Content of the DIRECT LINK data stream when reading sensor out.

Bit#	Description	Size[bit]	Remarks
[30:14]	Thermopile ADC counts	17	Value of thermopile voltage
[13:0]	Temperature ADC counts	14	Value of internal temperature reference

ADC counts The data represents ADC counts after low-pass filtering and the reference temperature counts. The low-pass data is represented as 17 bit unsigned integer. The reference temperature data is represented as 14 bit unsigned integer.

Figure 8: Data Transmission Diagram



Timing The DIRECT LINK interface communication principle is sketched in figure 8. It can be divided into the start condition and the data stream after it.

The sensor is expecting the host system to initiate the communication. Forcing DIRECT LINK to HIGH for at least $t_{DS} = 90\,\mu s$ and then pulling it to LOW will start the communication. The host system can resume with the **Readout of Bits**.

If the host system is not initiating the communication for a period of longer than $t_{SMPL} = 14.6\,ms$ the sensor will pull the line HIGH. This must be avoided by continious readout to avoid unnesseceray heatup of the component.

Readout of Bits The readout procedure is started by the forced pulse. The DigiPile™ waits for the next LOW to HIGH transition by the host system. The host system pulls the line HIGH and releases it (high impedance Z). The DigiPile™ will pull the line LOW for a 0 bit state or keep it HIGH for a 1 bit state.

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The time t_{BS} which the signal needs to settle to a LOW level depends on the capacitive load (e.g. PCB design) at the DIRECT LINK pin. Hence, it is recommended to start implementing the interface with t_{BIT} close to, but shorter than 25 µs to ensure proper LOW level settling. In next steps reduce t_{BIT} empirically to optimize for reliable data transmission at maximum transmission speed.
After reading the line state by the host system, the host pulls the line again LOW to initiate the next bit readout by a LOW to HIGH transition again. The sequence will be repeated until all bits are shifted out. After the last bit of bit[0] the host controller must force DIRECT LINK pin to LOW for at least $t_{UP} = 70$ µs and subsequently release DIRECT LINK (High Z).
It has to be considered that t_{BIT} must not exceed 25 µs to avoid data corruption. Under no circumstances DIRECT LINK may be at LOW level for longer than 25 µs . It is recommended that the total time to readout one data packet should not exceed 800 µs to ensure always latest values.
In order to reduce settling effects, the data packets have to be read continuously with equal sampling intervals.

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8 Packaging

The Excelitas Technologies tube packaging system protects the product from mechanical and electrical damage and is designed for manual unloading. Figure 9 shows the basic outline.
The devices are loaded sequentially and fixed with stoppers.Up to 48 parts are filled into one tube. In total up to 40 tubes are placed in one paper box.
Information labels, ESD labels and bar-code Labels are placed on the box. The label contains the following Information:

- Producer = Excelitas Technologies
- Origin
- Product Name
- Full BAU (unique identification) number
- Batch Number
- Packaging Date

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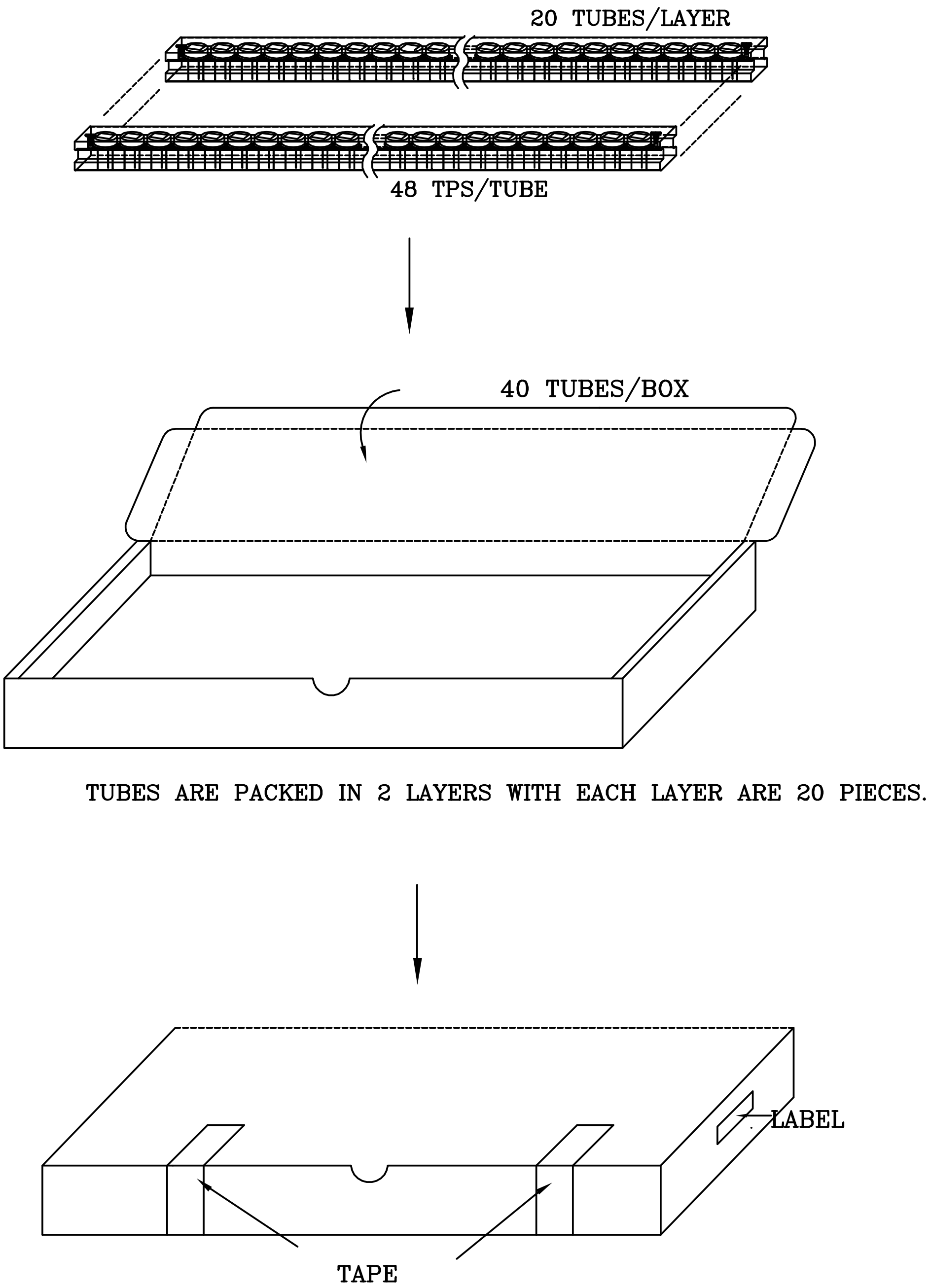
Figure 9: Information about the packaging of sensors.



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9 Statements

Quality Excelitas Technologies is a ISO 9001:2015 certified manufacturer with established SPC and TQM. Excelitas Technologies is certified for it's Environmental Management System according to ISO 14001:2015 and for the Occupational Safety and Health Management System according to ISO 45001:2018.
All devices employing PCB assemblies are manufactured according IPC-A-610 class 2 guidelines.
The infra-red detection product line is certified for ANSI/ESD S.20.20:2014.

Package This IR-detector is sealed to pass a He-leakage test with maximum leak rate of 1×10^{-8} mbar L s^{-1}.

Cleanliness Avoid touching the detector window. To clean windows, use only ethyl alcohol with a cotton swab when necessary. Do not expose detectors to aggressive detergents such as Freon, trichloroethylene, etc.

Tracability The marking of the detector includes the principal type, a 4 digit number that represents the Excelitas identification number. A 4 digit date code is provided in addition to that. It consists of the production year and week. The marking is printed on the top or side of the detector.

Moisture Sensitivity Level Moisture sensitivity level classification does not apply to TO-can products and parts with connectors. Storage at high humidities should be avoided.

Electrostatic Discharge Performance All pins pass the electrostatic discharge sensitivity (ESD) test level 1 (± 2 kV) according to IEC 61000-4-2. Please make sure not to confuse this norm with other norms such as ANSI/ESDA-JEDEC JS-001-2010 (Human Body Model), ESD DS5.3.1 (Charge Device Model) or ESD STM5.2 (Machine Model).

Mechanical Avoid mechanical stress on the housing and especially on the leads. Be careful when cutting or bending leads to avoid damage. Do not bend leads less than 5 mm from their base. Do not drop detectors on the floor.

RoHS This sensor is a lead-free component and complies with the current RoHS regulations, especially with existing road-maps of lead-free soldering.

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Customers considering the use of Excelitas Technologies devices in applications where failure may cause personal injury or property damage, or where extremely high levels of reliability are demanded, are requested to discuss their concerns with Excelitas Technologies representatives before such use.
The Company's responsibility for damages will be limited to the repair or replacement of defective product. As with any semiconductor device, pyroelectric sensors, thermopile sensors or modules have a certain inherent rate of failure. To protect against injury, damage or loss from such failures, customers are advised to incorporate appropriate safety design measures into their product.

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