AN5983

Application note

Hardware implementation guidelines for the STHS34PF80 infrared sensor

Introduction

This purpose of this application note is to provide hardware design guidelines based on ST's evaluation kit and guidelines for the integration of the cover/lens to ensure the performance of the STHS34PF80 IR sensor in the final application.

The STHS34PF80 is an uncooled, factory-calibrated IR sensor based on TMOS technology with an operating wavelength between 5 μm and 20 μm. It is designed to measure the amount of infrared radiation emitted from an object within its field of view (FOV). The measured information is digitally processed to monitor presence, motion, and an overtemperature condition and the device is capable of detecting an object at a distance up to 4 meters without any optical lens.

ST provides a reference evaluation kit that has been meticulously designed for portability and effortless mounting on any surface to support customer evaluation and validation for applications. The adapter board compact dimensions of 33 mm x 25 mm enable seamless lens integration in case the application requires a longer range or wider FOV detection.

This document does not modify the content of the official datasheet. Refer to the datasheet for parameter specifications.

1 Overview

This document introduces the key features of the STHS34PF80 infrared sensor and related design guidelines for the circuit, PCB layout, and lens/cover integration in the final application.

1.1 STHS34PF80 IR sensor overview

STHS34PF80 is fabricated by merging SOICMOS and MEMS technologies, achieving high performance and flexibility in a small package with minimum footprint. The STHS34PF80 IR sensor is able to detect radiation emitted by a body at a certain temperature according to blackbody emission Plank's law. This feature enables the sensor to work as a human presence and motion sensor in different application contexts such as alarm systems, anti-intruder systems, smart lighting, and room occupancy.

Specific features for the sensor are indicated below.

Key features

- High sensitivity for working as a presence and motion sensor
- Range up to 4 meters without lens
- Integrated silicon IR filter
- SMD friendly
- Capable of detecting stationary objects
- Capable of distinguishing between stationary and moving objects
- 80° field of view
- Factory calibrated
- Low power
- Programmable interrupt

Electrical specifications

- Supply voltage: 1.7 V to 3.6 V
- Supply current: 10 µA
- 2-wire I²C / 3-wire SPI serial interface
- Programmable ODRs from 0.25 Hz to 30 Hz
- One-shot mode

Sensing specifications

- IR sensitivity: 2000 LSB/°C
- Noise: 25 LSB RMS
- Operating wavelength: 5 µm to 20 µm
- Local temperature sensor accuracy: ±0.3°C

Package specifications

- Organic LGA 3.2 x 4.2 x 1.455 (max) mm, 10 leads
- ECOPACK and RoHS compliant

Applications

- Presence, motion, occupancy, and proximity sensing
- Alarm / security systems
- Home automation
- Smart lighting
- IoT
- Smart lockers
- Smart wall pads

1.2 STHS34PF80 IR sensor optical features

The STHS34PF80 is an uncooled, factory-calibrated, IR sensor with an operating wavelength between 5 µm and 20 µm. The transmittance is filtered by the embedded optical window on top of the package as shown in Figure 1.

It has been designed to perform an accurate measurement of the infrared radiation emitted by an object within its field of view (±40 deg.) as described in Figure 2. This information is digitally processed by the embedded ASIC and provided to the application processor. In addition, the sensor offers embedded algorithms for human presence and motion detection and specific interrupts. Specifically, STHS34PF80 is a highly sensitive sensor that enables detection of human presence at a distance up to approximately 4 meters without the use of any specific lens. The exact distance depends on environmental conditions. The application of a lens enables extending the sensor's reach.

System integration can be done by looking at the main mechanical and geometrical parameters and factors that influence the sensor performance, and thus optimizing those.

More specifically, parameters like sensitivity, field of view and other sensor features are mainly affected by geometrical features and the optical properties of the material for protecting the device from the external environment. These parameters depend on specific application constraints and operating conditions, so they need to be identified case-by-case and optimized as well, based on the considerations above.

Typically, the design optimization consists of determining the:

- Placement of the sensor in the system
- Sensor protection embodiment from dust, water, or chemical solvent by using a sensor chamber
- Optical system characteristics consisting of an exposure hole or lens

Figure 1. Typical transmittance curve

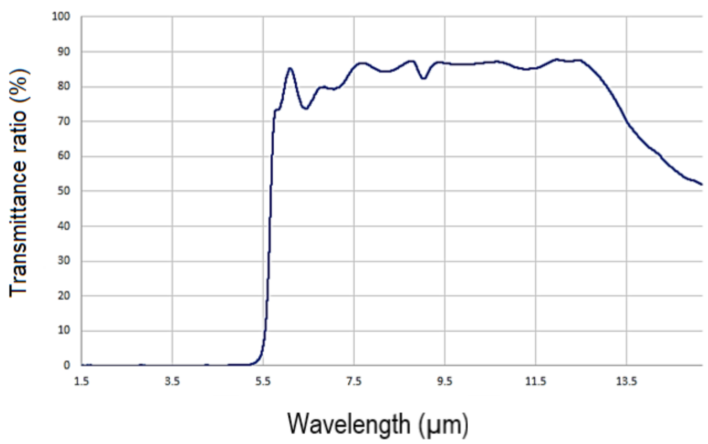
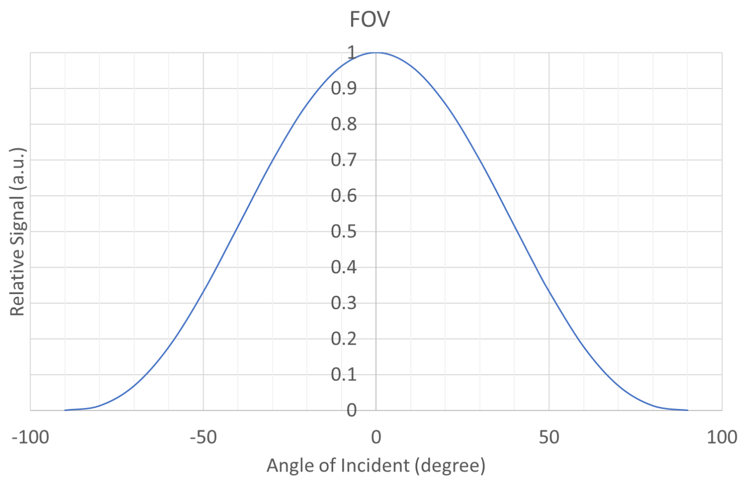


Figure 2. Typical field of view



2 Design guidelines for the exposure hole in the final application

The STHS34PF80 sensor can be used in conjunction with a cover or lens. The cover essentially can provide physical protection of the module, including dust prevention.

The **exposure hole** has to respect some geometrical constraints in order to avoid the FOV limitation.

The **cover material or lens** has to meet some optical requirements to guarantee the range. The cover material transmittance has to limit IR radiation losses, according to the device filter transmission spectrum, and FOV limitation.

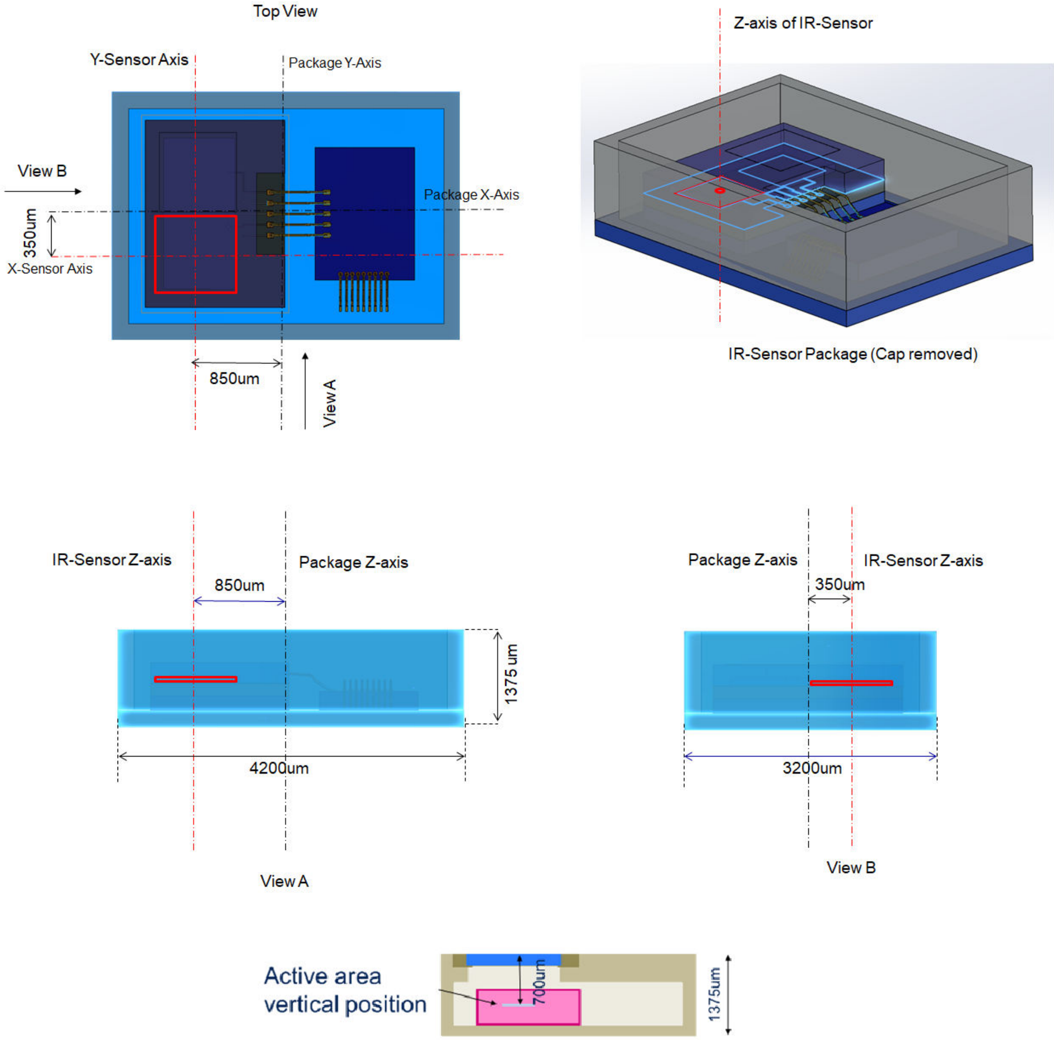
The cover material or lens can be made of *infrared*-transmitting polymers, HDPE (high-density polyethylene) but also of silicon, germanium, or chalcogenide. This choice depends on the transmission range, mechanical dimensions, and cost required by the final application.

The contributions of the optical (transmission/haze) and mechanical parameters to device performance can result in a reduction of partial sensitivity of the device.

The goal is to ensure that the impact of the cover material or lens on the performance of the STHS34PF80 is minimized.

The mechanical case of the final application needs to have the proper dimensions of the exposure hole and vertical position (Z-axis) correspond to the area of the sensing element (red box in Figure 3) on the package to maximize the performance of the STHS34PF80. Guidelines to design the proper dimensions and to align the vertical position between the exposure hole of the final application and the sensing element must be followed, refer to Figure 3.

Figure 3. Mechanical dimensions for optical alignment



In the design phase it is recommended to take into account the following highlighted points:

- Since the sensing element area (red box in Figure 3) is not positioned in the center of the package, the center of the exposure hole should be aligned to the center of the sensing element area (red box) and not to the center of the package.
- To have alignment of the vertical positions, it is recommended to find the center of the package and shift 350 μm on the X-axis and 850 μm on the Y-axis. Then, this position is the center of the sensing element area to be aligned with the exposure hole of the application case.
- The sensor embodiment shall allow collecting IR radiation without any obstacles to the radiation optical path. Shadow zones over the sensing area must be avoided if the intent is to preserve the sensor FOV.
- Minimizing the tolerance in the optical stack is crucial for consistent performance across the population.

Figure 4. **Example of application architecture and corresponding field of view**

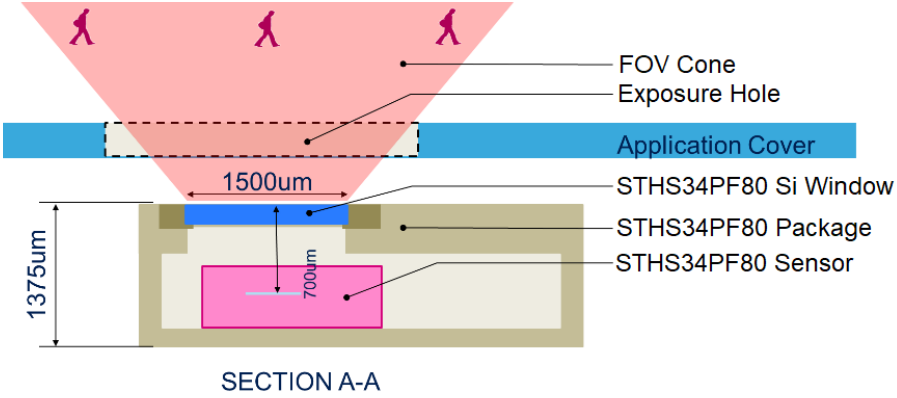
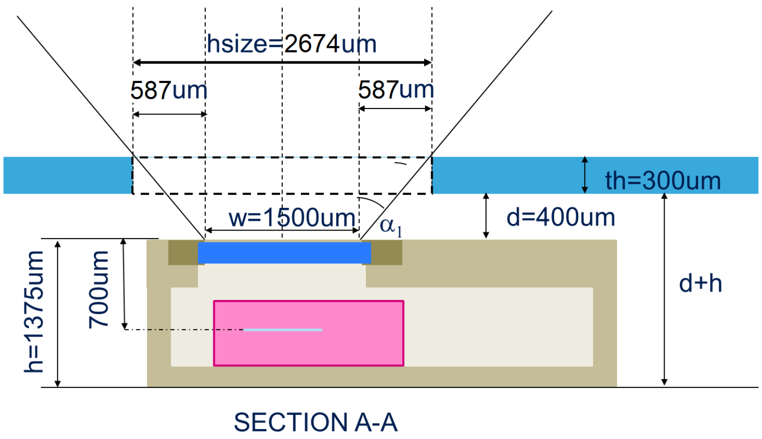


Figure 5 shows an example of the exposure hole position and dimensions. In the example, the hole is just open (without a cover or lens). The schematic is represented with the package typical dimensions.

Figure 5. **Example 1 of the exposure hole calculation**



Hole size can be calculated using the following formula:

$$hsize = 2\tan(\alpha) \cdot (d + th) + w \quad (1)$$

where:

- α is the STHS34PF80 field of view (40º).
- w is the width of the optical window.
- hsize is the exposure hole lateral dimension.
- th is the application case thickness.
- d is the distance between the top of the sensor and the bottom of the application case.

with the following assumptions:

- FOV = ±40º (total field of view)
- w = 1500 µm (optical window width)
- d = 400 µm (distance from the top of the package to the exposure hole)
- th = 300 µm (exposure hole thickness)
- h = 1375 µm ±80 µm (sensor package nom. thickness)

$$hsize = 2\tan(40\ \mathrm{deg}) \times\ (300 + 400)\mu m +\ 1500\mu m \approx 2674\mu m$$

Additionally, around 135 µm tolerance (based on the calculation in the formula above, given an 80 µm package height tolerance) needs to be considered as well as other tolerances (that is, the thickness of the case) that are not considered in this calculation.

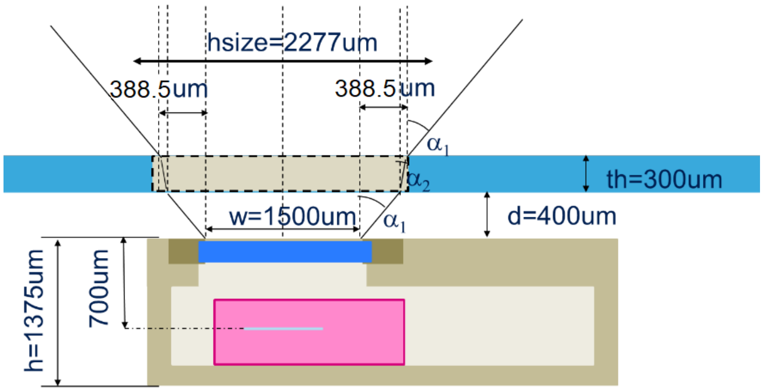
The following equation can be applied for an exposed hole without a cover. If a cover is used, the deflection due to the screen different refractive index with respect to the air must be considered (Snell equation):

$$\frac{n_1}{n_2} = \frac{\sin(\alpha_2)}{\sin(\alpha_1)}$$

where:

- n_1 is the air refractive index.
- n_2 is the screen material refractive index.
- α_1 and α_2 are the ray angles in the two materials as indicated in Figure 6.

Figure 6. Example 2 of the exposure hole calculation



In this case, Equation 1 can be modified to Equation 2 as follows:

$$hsize = 2\tan(\alpha_1)\cdot(d) + 2\tan(\alpha_2)\cdot(th) + w \tag{2}$$

If the cover window is made of silicon for example, $n_2 = 3.4$, $n_1(\text{air}) = 1$, so $\alpha_1 = 40°$ $\alpha_2 = 10°$ and applying Equation 2:

$$hsize = 2\tan(40\,\text{deg})\cdot(400)\mu m + 2\tan(10\text{deg})\cdot(300)\mu m + 1500\mu m \approx 2277\mu m$$

Additionally, around 134 µm tolerance (based on the calculation in the formula above, given an 80 µm package height tolerance) needs to be considered as well as other tolerances (that is, the thickness of the case) that are not considered in this calculation.

Finally, an ideal cover window design should have:

- No structural defects in the plastic, glass, or semiconductor material
- No surface defects that can induce light scatter or smudge sensitivity with fingerprint
- Transmission >90% in the IR region indicated by the application (for example from 8 µm to 12 µm for human body application)
- Low window tilt <2 degrees
- Tight tolerances

In this context, it is recommended to monitor the:

- Presence of surface and structural defects
- Cover window IR transmission
- Level of scatter (clarity or haze), as an indicator of the transmitted light that may be lost in scattering and which can impact the overall system
- Mechanical assembly tolerance

3 Design guidelines for cover/lens integration

The selection of the appropriate cover/lens depends on the target FOV (field of view) as the aperture and range to be achieved for fulfilling the application requirements.

All the geometrical considerations exposed in the previous section regarding the FOV shadowing and the lens centering and materials have to be reviewed on the basis of some additional specific constraints due to lens geometrical optical features such as, for example, the focal length and the optical aperture.

Also, the transmission efficiency plays a key role in the choice of the cover material and lens, which have to be as transparent as possible to these wavelengths. In this case, the cover and lens can be made from silicon, germanium, chalcogenide or polymers, and HDPE (high-density polyethylene). A Fresnel lens could be an option since it is a common lens with attenuation of IR radiation, easy to mount, and low cost. This choice depends on the transmission range indicated by the application and on the final application requirements.

These features are strongly correlated to the ability of the cover/lens to collect infrared radiation from the field of view at the wavelength range of the sensor itself.

Every lens and cover material has its own characteristics such as transmittance and emissivity. These parameters can introduce different contributions that can cause incorrect temperature compensation:

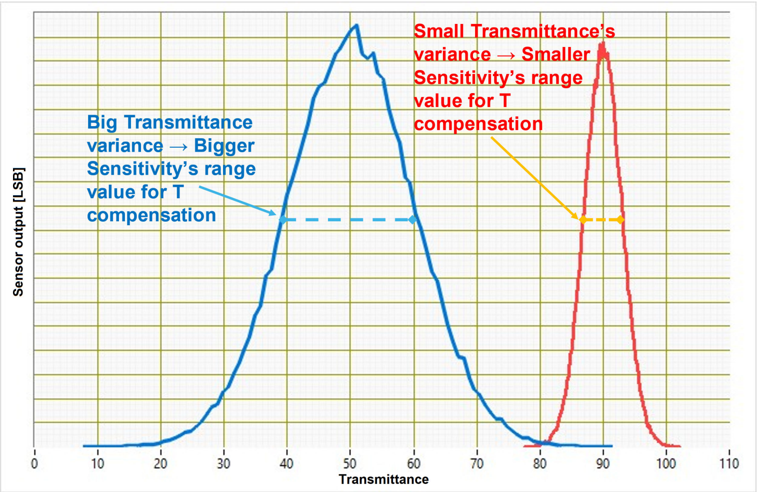
- **Transmittance** is the amount of IR radiation that “successfully” passes through the substance to the other side. Each lens and cover material has its own transmittance. The characteristics in the same lot of the same item can vary due to the manufacturing process. As a result, it may cause variation in the measurement of the IR radiation in the final application and may cause additional error by compensating the temperature variation if it is required in the final application.
- **Emissivity** is the measure of an object’s ability to emit infrared energy. Some materials used for covers and lenses have a high emissivity factor. The amount of IR radiation emitted by the cover is detected by the IR sensor, introducing additional IR radiation, which can impact the error of the IR radiation measurement. It is recommended to use a cover with very low emissivity to avoid an undesired contribution in the measurement.

With regard to this issue, it is mandatory to analyze the final application of the sensor. Based on the application, it is recommended to avoid using a cover on the sensor unless it is essential, due to dust, contamination, and so forth.

If the cover is necessary, it is important to choose a lens or cover material with the following requirements:

- Lowest transmittance variance. Thus, the range of sensitivity values to be chosen for the temperature compensation is smaller. As a result, the error introduced is minimized (refer to the following figure).

Figure 7. Transmittance variance



- Emissivity as low as possible to avoid any extra IR interaction between the cover material and sensor, which might cause incorrect temperature compensation with both embedded and extra software compensation.

3.1 Reference lens of the STHS34PF80 in the final application

The STHS34PF80 is a highly sensitive sensor that detects human presence at a distance up to approximately 4 meters within an 80 deg. FOV without the use of any specific optical lens. ST has proposed the following two different lenses to introduce the capabilities in terms of long distance and/or wide FOV by implementing different lenses in the final application. A customized lens might be required in the final application depending on the target KPI for the application level.

3.1.1 Extending to a longer distance with the TMOS63-10 lens

The TMOS63-10 lens is designed by the Fresnel Factory and is suitable for long-distance detection with a narrow FOV. It can be used for occupancy detection. The performance can vary according to the test settings and room condition.

The mechanical dimensions of the TMOS63-10 lens are indicated in Figure 8. The lens must be assembled with the grooved surface facing outward from the sensor.

Detailed lens information can be found on the Fresnel Factory website (TMOS63-10).

Figure 8. Mechanical dimensions of the TMOS63-10 lens

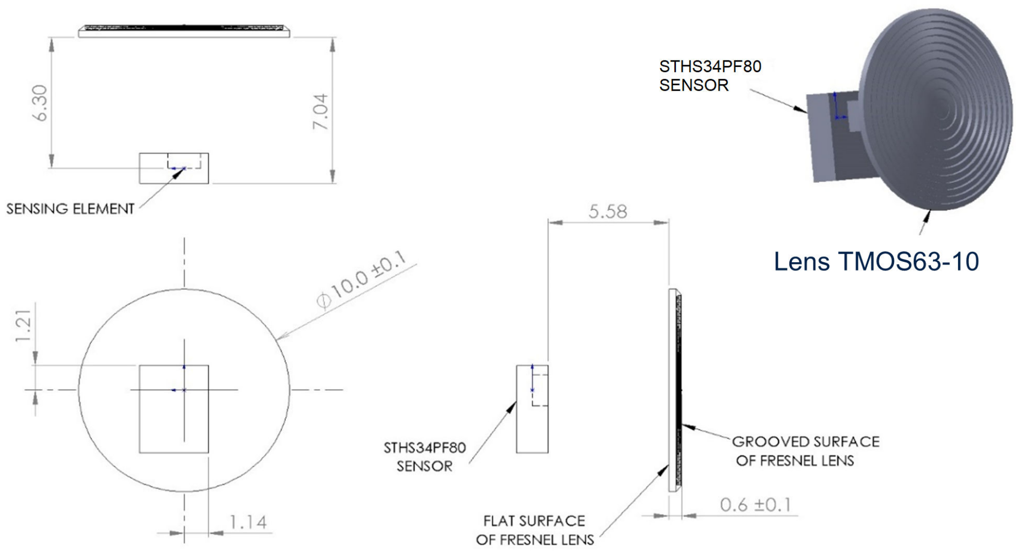
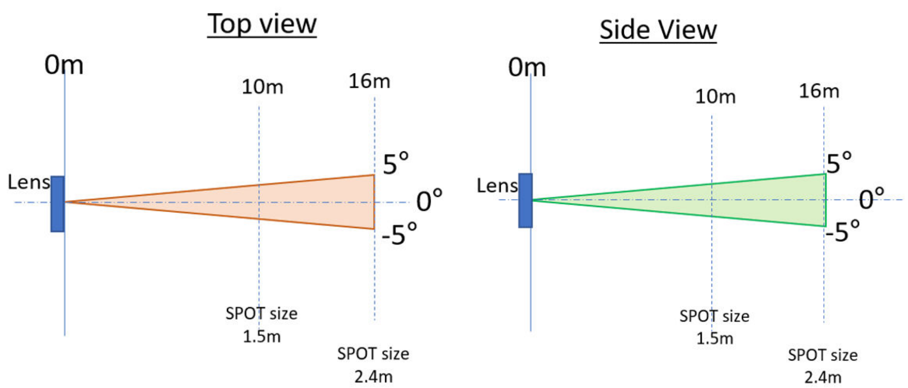


Figure 9. Detectable field of view and distance of TMOS63-10



The TMOS63-10 lens is included in the ST evaluation kit (STEVAL-MKI1231KA) for the STHS34PF80 IR sensor. Figure 10 shows how the evaluation board is assembled with the TMOS63-10 lens.

Figure 10. **Evaluation kit with TMOS63-10 lens**

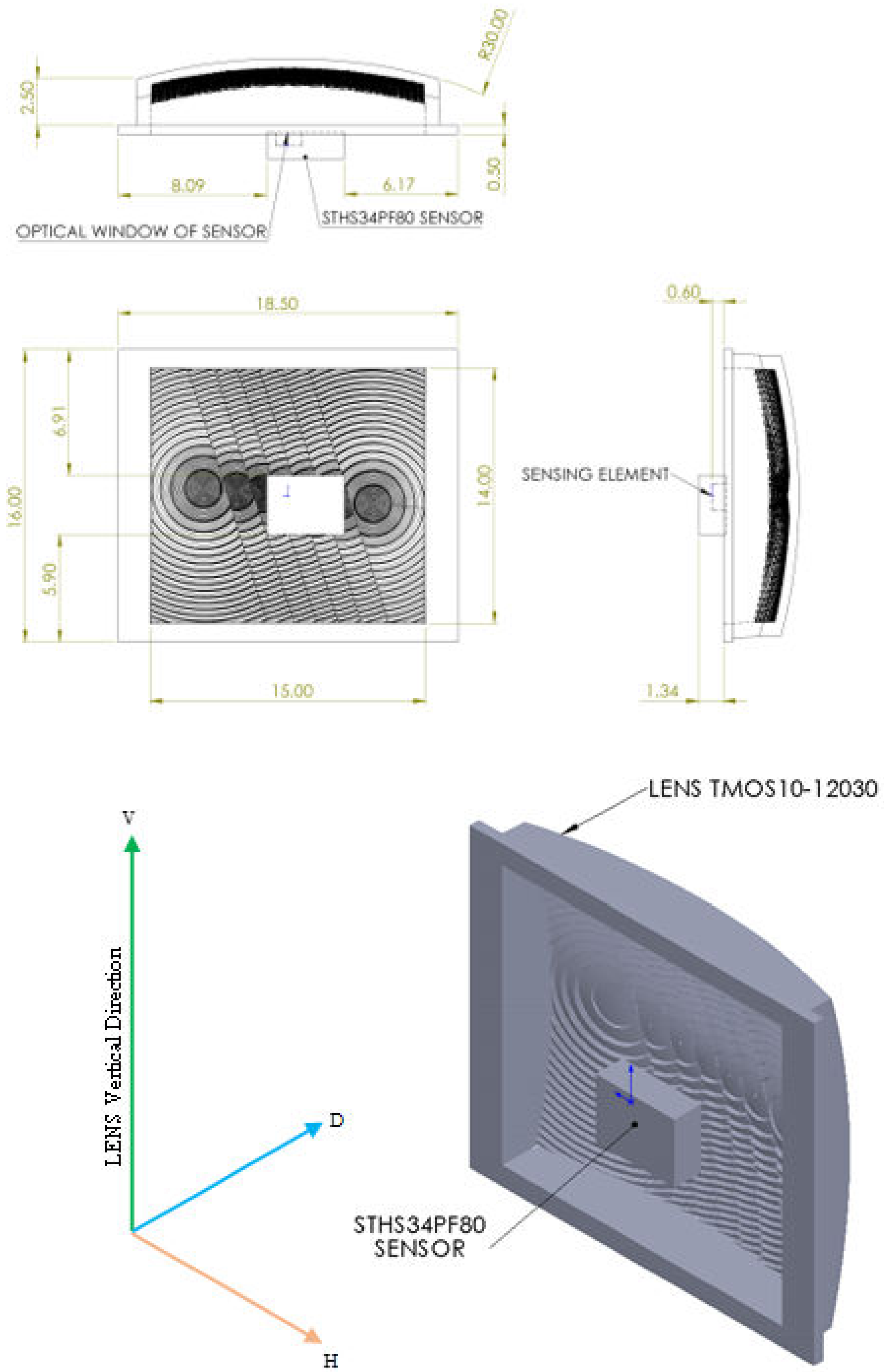
The lens holder can be 3D printed and the 3D drawing file for 3D printing can be downloaded at the following link: 3D lens holder for TMOS63-10

3.1.2 Extending to a wider field of view with the TMOS10-12 lens

Another lens for the STHS34PF80 to support a wider FOV and mid to long distance detection is the TMOS10-12 from the Fresnel Factory. This lens is suitable for wall-mounted applications for presence/movement detection. The performance can vary according to the test settings and room condition.

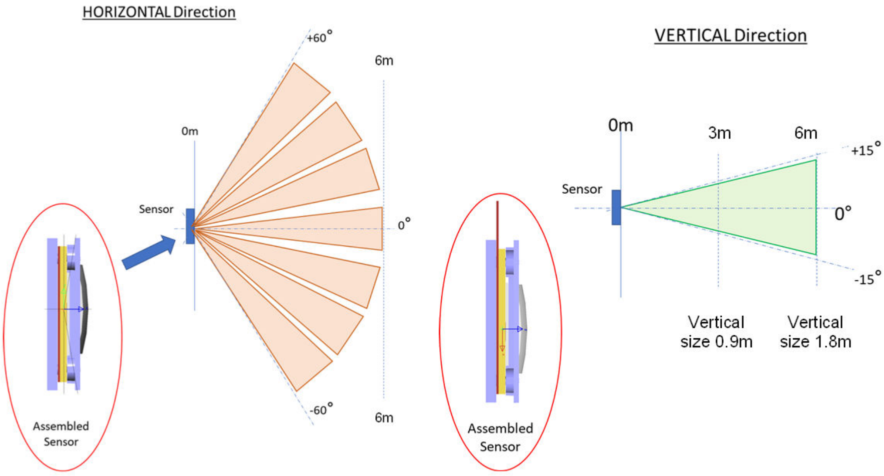
The mechanical dimensions of TMOS10-12 are described in Figure 11.

Figure 11. Mechanical dimensions of the TMOS10-12 lens



The TMOS10-12 supports a wide field of view of 120 degrees in a horizontal direction and 30 degrees in a vertical direction as indicated in Figure 12.

Figure 12. **Detectable field of view and distance of TMOS10-12**



The lens of TMOS10-12 is not included in the ST evaluation kit, but the lens can be purchased from the Fresnel Factory or Digikey. The files for 3D printing of the lens holder can be downloaded from the Fresnel Factory using the link below. Figure 13 shows an example of the lens assembly with the lens holder on the STHS34PF80 evaluation board.

Figure 13. **Evaluation kit with TMOS10-12 lens**

Download the 3D STP files for 3D printing at the link below from the Fresnel Factory website:

3D lens holder for TMOS10-12

4 Heat sources

The presence of sources of heat near the sensor can reduce performance by modifying the sensor sensitivity. Depending on the position and type of source, heat can be propagated based on different mechanisms. Convective heat and local thermal sources around the sensor can modify the temperature of the sensing area. Typical sources are as follows:

- Power management devices
- Processors and microcontrollers
- LCD displays

Therefore, the sensor has to be placed at the correct distance from these heat sources. In addition, it is recommended to adopt thermal insulation structures inside the embodiment, if necessary. It is also recommended, according to the specific layout, to implement a vent aperture close to the heat source, acting as a cooling channel if allowed by application constraints. As a second mechanism, we highlight the thermal conduction that can mostly occur through PCB metal lines. In order to reduce this effect, we recommend adopting thin metal lines around the sensor, at an appropriate distance from the sensor and potential heat sources, avoiding metal areas near and under the device. Furthermore, to improve sensor thermal decoupling from the system, it is recommended to create trenches near the sensor (refer to Figure 19) and remove all unnecessary metal from the PCB around the sensor. In both cases of thermal propagation, an infrared thermal analysis of the whole system, running under different operating conditions, it is the recommended approach for identifying the appropriate location of the sensor.

5 Mechanical stress

Placement of the sensor shall be appropriate in order to avoid any mechanical force applied to the sensor, either directly due to an incorrect design of the mechanical system, or indirectly due to user interaction with the system itself. These recommendations are for avoiding any potential misalignment between the lens and sensor over time and for avoiding any physical damage to the component.

Any potential contribution of device tilting with respect to the optics should be evaluated carefully, including soldering.

Finally, potential vibration close to the sensor could propagate to the sensor by causing additional noise affecting the IR signal measurement.

Therefore, it is recommended to consider all of these elements during the design phase.

6 Light sources

Sources of light (like the sun, fluorescent light, and so forth) do not impact the functionality of the IR sensor thanks to the embedded optical window, which has a 5 μm ~ 20 μm wavelength transmittance. However, the temperature variation from the light source to the area of the FOV or to the sensor itself might cause additional noise or output drift.

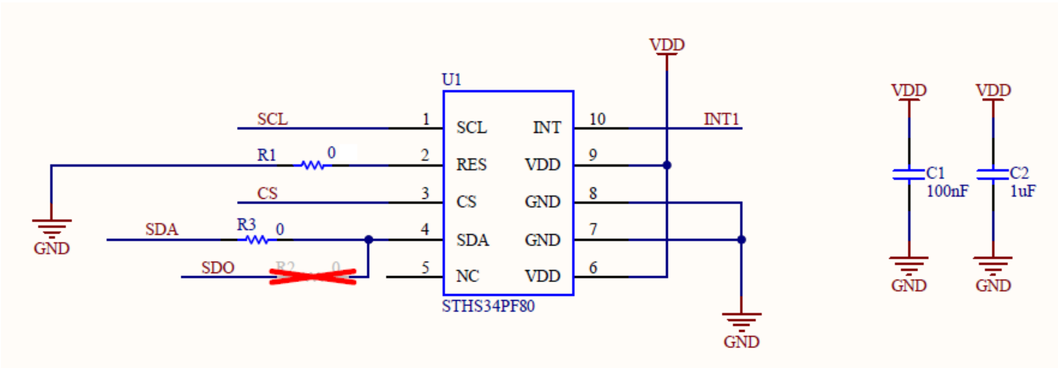
7 STHS34PF80 circuit and PCB layout guidelines

7.1 STHS34PF80 reference circuit based on the evaluation board

For customer reference, Figure 14 depicts the circuit used for the evaluation board.

In the circuit, C_1 = 100 nF and C_2 = 1 µF capacitors are required to improve the voltage supply rejection ratio (robust PSRR) and they must be placed as close as possible to the sensor. R_3 and R_2 are configured according to the I²C and SPI interface required in the application.

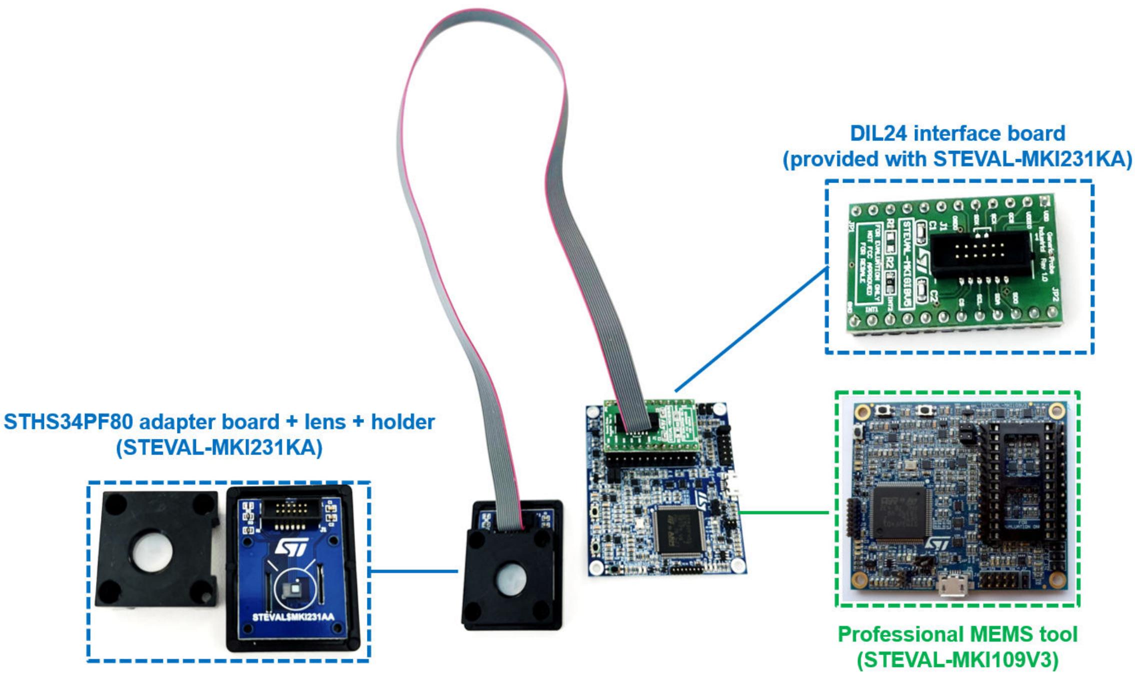
Figure 14. Circuit of the STHS34PF80 evaluation board



The STHS34PF80 evaluation kit is composed of an STHS34PF80 adapter board, lens holder, lens, DIL24 interface board, and a cable to connect to the Professional (Profi) MEMS tool as shown in Figure 15.

The STHS34PF80 evaluation kit can be ordered from www.st.com using order code STEVAL-MKI231KA and the Profi MEMS tool can be ordered using the order code STEVAL-MKI109V3.

Figure 15. STHS34PF80 evaluation board

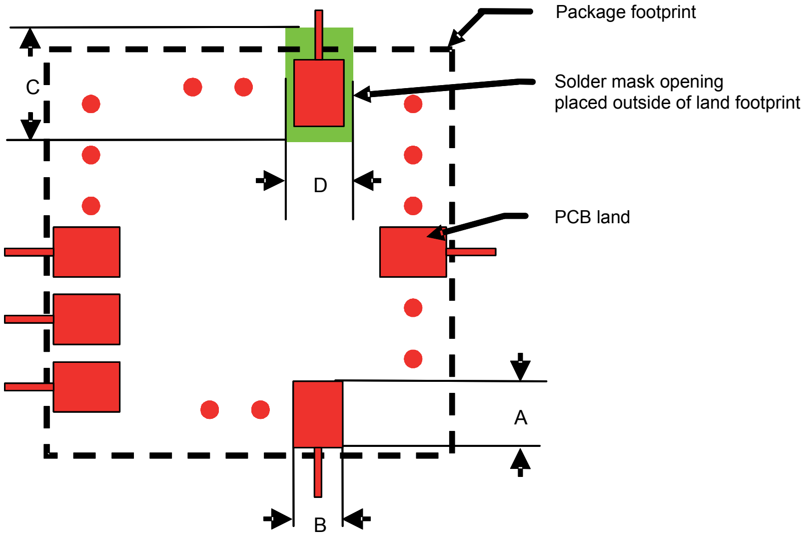


7.2 PCB guidelines

To guarantee proper device operation, follow the PCB guideline rules below.

For further information, refer to technical note TN0018.

Figure 16. **Example of PCB lands (LGA package)**



PCB land design and connecting traces should be designed symmetrically.

For LGA pad spacing greater than 200 µm:

A = PCB land length = LGA solder pad length + 0.1 mm

B = PCB land width = LGA solder pad width + 0.1 mm

For LGA pad spacing equal to or less than 200 µm:

A = PCB land length = LGA solder pad length

B = PCB land width = LGA solder pad width

C = Solder mask opening length (where applicable) = PCB land length + 0.1 mm

D = Solder mask opening width = PCB land width + 0.1 mm

Stencil design and solder paste application

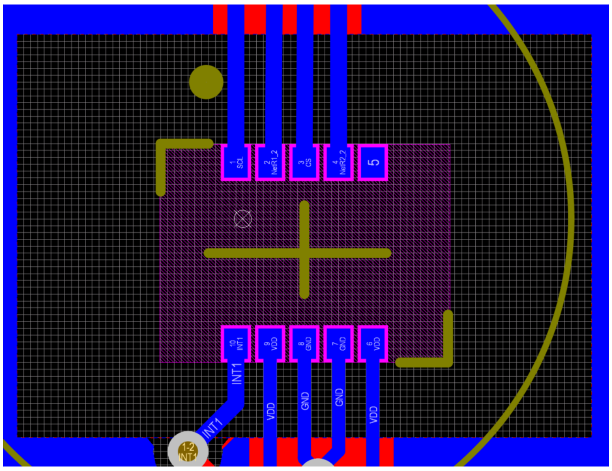
The thickness and the pattern of the soldering paste are important for the proper sensor mounting process.

- Stainless steel stencils are recommended for solder paste application.
- A stencil thickness of 90 - 150 µm (3.5 - 6 mils) is recommended for screen printing.
- The openings of the stencil for the signal pads should be between 70% and 90% of the PCB pad area.
- Optionally, for better solder paste release, the aperture walls should be trapezoidal and the corners rounded.
- The fine pitch of the IC leads requires accurate alignment of the stencil to the printed circuit board. The stencil and printed circuit assembly should be aligned to within 25 µm (1 mil) prior to application of the solder paste.

Traces

- Connecting traces should be designed symmetrically.
- All the traces should flow outside the component parallel to the long edge of the pad.
- The traces must be all the same thickness. All traces have the same thickness to avoid potential mechanical stress induced on the device. There is no need for thicker power/gnd traces since the device draws very low current.
- The ground plane should not be connected directly to the footprint pads. It is better to connect it through a standard trace.

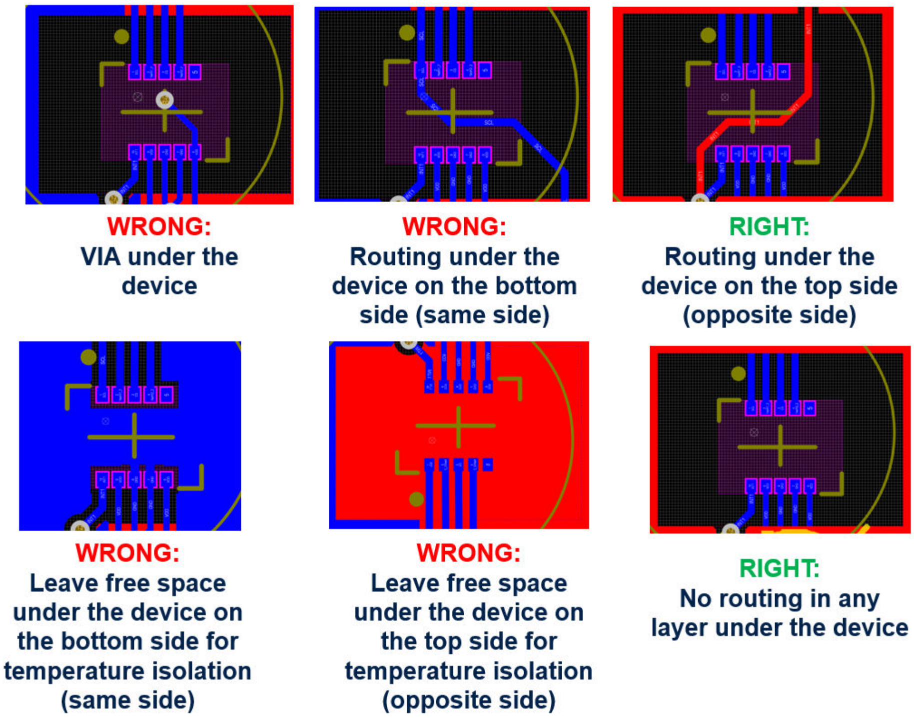
Figure 17. Recommended traces



Placement

- Follow the recommended placement guidelines when the STHS34PF80 is placed on the bottom side of the PCB.
- Never place any routing (traces) or VIA on the bottom side under the device (that is, the same side of the PCB where the sensor is placed).
- A power plane or signal routing can be routed on the top side of the PCB (that is, the opposite side of the PCB where the sensor is placed).

Figure 18. Recommended placement options



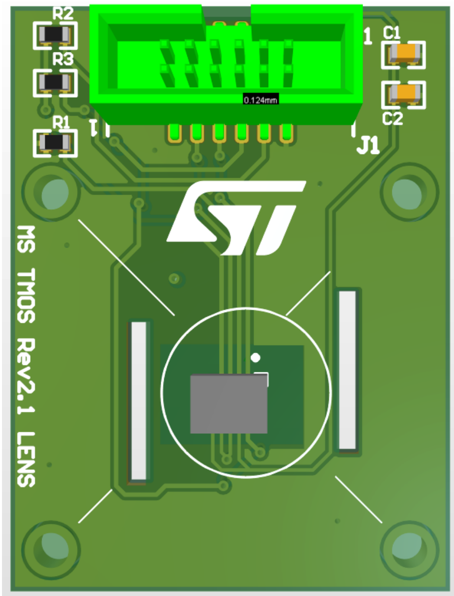
Trenches

In order to avoid or to reduce to the minimum any heat transmission from the board to the sensor, it is a good practice to place trenches around the device as shown below in Figure 19, as an example in the final application.

This feature is already present in the evaluation board as two opposite and parallel trenches around the sensor.

In this way, ambient temperature compensation is more effective since the STHS34PF80 is better isolated with trenches for heat sources on the PCB.

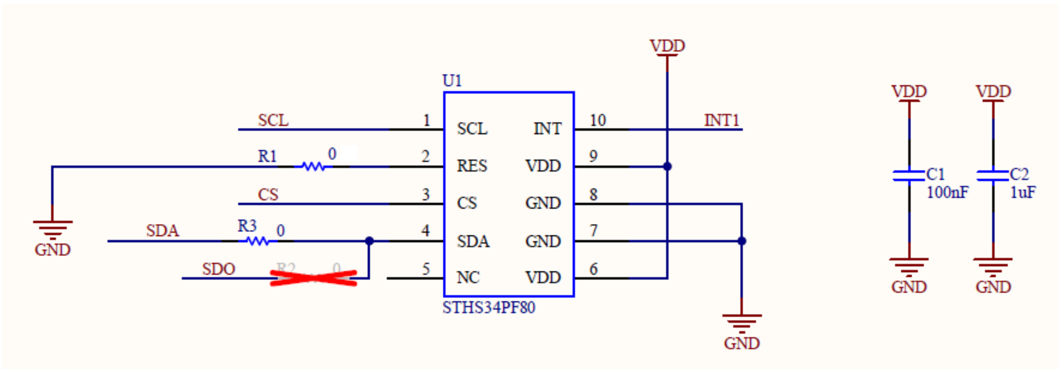
Figure 19. ST evaluation board PCB with trenches near the sensor



7.3 EMI robustness

Sensor performance might be degraded by RF noise, depending on how the PCB layout is designed in the final application. It is highly recommended to add decoupling capacitors C1 (100 nF) and C2 (1 μF) on the VDD line and place them as close as possible to the sensor to avoid noise on VDD. For some final applications, the decoupling capacitor (C2) might be selected as either 1 μF or 100 pF depending on the requirement for EMI robustness or noise on the VDD line. This must be evaluated in the final application in case only one decoupling capacitor can be used to save space on the PCB.

Figure 20. Circuit of STHS34PF80 evaluation board

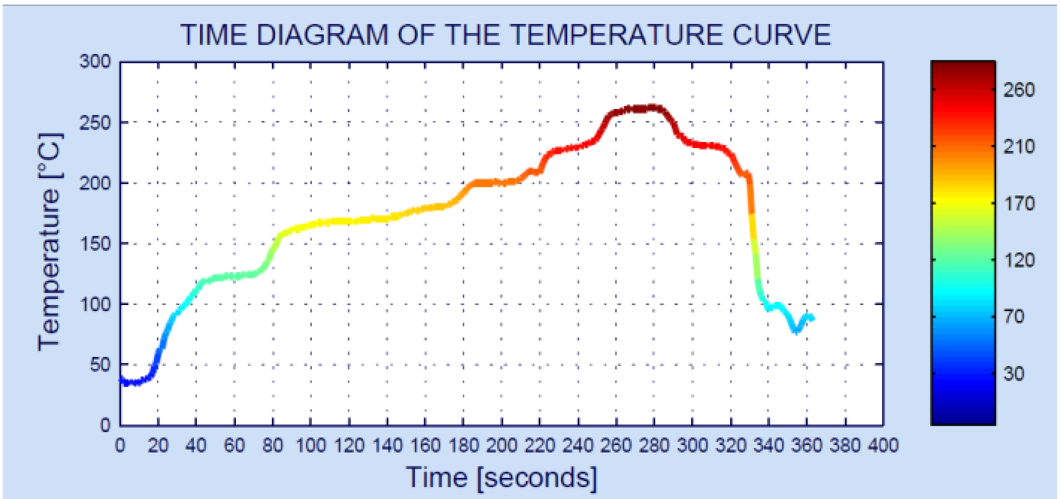


8 Reflow and cleaning guidelines

Based on the JEDEC standard J-STD-020, it is recommended to not exceed temperatures of the profiles defined by JEDEC.

Specification: IPC-JEDEC J-STD-020

Figure 21. Soldering profile



For the cleaning process, ultrasonic cleaning is not allowed due to potential damage to the MEMS structure. In case cleaning is required after soldering or an assembly process, manual cleaning of the optical window using isopropyl alcohol can be performed.

Revision history

Table 1. **Document revision history**

Date	Version	Changes
02-Oct-2023	1	Initial release

Contents

List of figures