9 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

9.1 Application Information

Ambient light sensors are used in a wide variety of applications that require precise measurement of light as perceived by human eye, since they have a specialized filter that mimic human eye. The following sections shows crucial information about integrating OPT4001 in applications.

9.2 Typical Application

9.2.1 Electrical Interface

The electrical interface is quite simple, as illustrated in Figure 9-1 below. Connect the OPT4001 I^2C SDA and SCL pins to the same pins of an applications processor, micro controller, or other digital processor. If that digital processor requires an interrupt resulting from an event of interest from theOPT4001, then connect the INT pin to either an interrupt or general-purpose I/O pin of the processor (Only for the SOT-5X3). There are multiple uses for this INT pin, including triggering a measurement on one-shot mode, signaling the system to wake up from low-power mode, processing other tasks while waiting for an ambient light event of interest, or alerting the processor that a sample is ready to be read.. Connect pullup resistors between a power supply appropriate for digital communication and the SDA and SCL pins (because the pins have open-drain output structures). If the INT pin is used, connect a pullup resistor to the INT pin. A typical value for these pullup resistors is 10 kΩ. The resistor choice can be optimized in conjunction to the bus capacitance to balance the system speed, power, noise immunity, and other requirements.

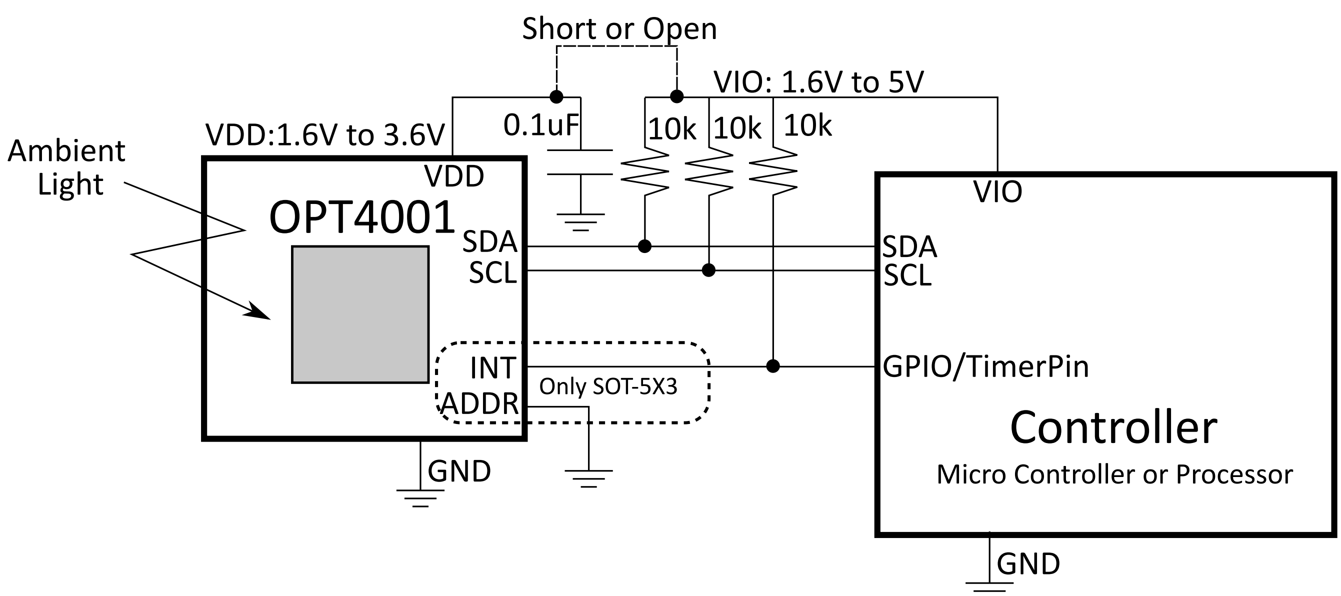


Figure 9-1. Typical Application Schematic

The power supply and grounding considerations are discussed in the *Section 9.4*.

Although spike suppression is integrated in the SDA and SCL pin circuits, use proper layout practices to minimize the amount of coupling into the communication lines. One possible introduction of noise occurs from capacitively coupling signal edges between the two communication lines themselves. Another possible noise introduction comes from other switching noise sources present in the system, especially for long communication lines. In noisy environments, shield communication lines to reduce the possibility of unintended noise coupling into the digital I/O lines that can be incorrectly interpreted.

9.2.1.1 Design Requirements

9.2.1.1.1 Optical Interface

The optical interface is physically located on the same side of the device pins as the electrical interface for the PicoStar™ variant and facing away from the pins for the SOT-5X3 variant, as shown in Figure 9-2 and Figure 9-3

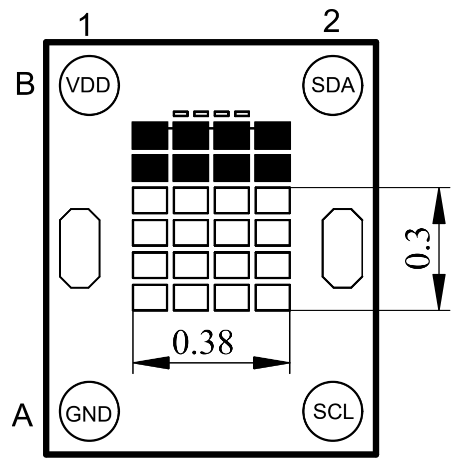


Figure 9-2. Sensor Position on PicoStar™ Variant

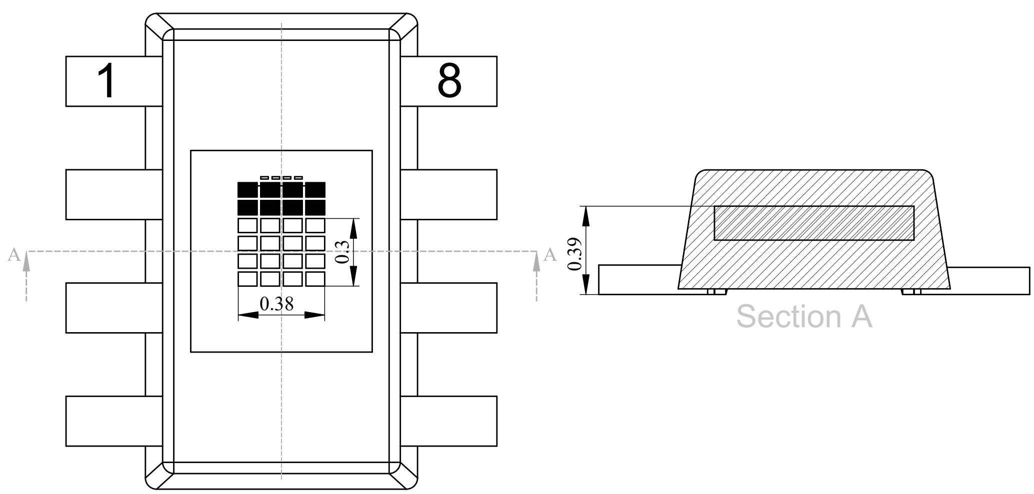


Figure 9-3. Sensor Position on the SOT-5X3 Variant

In case of the PicoStar™ variant systems, light that illuminates the sensor must come through the FPCB. Typically, the best method is to create a cutout area in the FPCB. Other methods are possible, but with associated design tradeoffs. This cutout must be carefully designed because the dimensions and tolerances impact the net-system, optical field-of-view performance. The design of this cutout is discussed more in the *Section 9.5.2*.

Physical components, such as a plastic housing and a window that allows light from outside of the design to illuminate the sensor (see Figure 9-4), can help protect the device and neighboring circuitry. Sometimes, a dark or opaque window is used to further enhance the visual appeal of the design by hiding the sensor from view. This window material is typically transparent plastic or glass.

Generally for both package variants, any physical component that affects the light that illuminates the sensing area of a light sensor also affects the performance of that light sensor. Therefore, for the best performance, make sure to understand and control the effect of these components. Design a window width and height to permit light from a sufficient field of view to illuminate the sensor. For best performance, use a field of view of at least ±35°, or preferably ±45° or more. Understanding and designing the field of view is discussed further in application report *OPT3001: Ambient Light Sensor Application Guide* (SBEA002).

The visible-spectrum transmission for dark windows typically ranges between 5% to 30%, but can be less than 1%. Specify a visible-spectrum transmission as low as, but no more than, necessary to achieve sufficient visual appeal because decreased transmission decreases the available light for the sensor to measure. The windows are made dark by either applying an ink to a transparent window material, or including a dye or other optical substance within the window material itself. This attenuating transmission in the visible spectrum of the window creates a ratio between the light on the outside of the design and the light that is measured by the device. To accurately measure the light outside of the design, compensate the device measurement for this ratio.

Although the inks and dyes of dark windows serve their primary purpose of being minimally transmissive to visible light, some inks and dyes can also be very transmissive to infrared light. The use of these inks and dyes further decreases the ratio of visible to infrared light, and thus decreases sensor measurement accuracy. However, because of the excellent red and infrared rejection of the device, this effect is minimized, and good results are achieved under a dark window with similar spectral responses.

For best accuracy, avoid grill-like window structures, unless the designer understands the optical effects sufficiently. These grill-like window structures create a nonuniform illumination pattern at the sensor that make light measurement results vary with placement tolerances and angle of incidence of the light. If a grill-like structure is desired, then the device is an excellent sensor choice because the device is minimally sensitive to illumination uniformity issues disrupting the measurement process.

Light pipes can appear attractive for aiding in the optomechanical design that brings light to the sensor; however, do not use light pipes with any light sensor unless the system designer fully understands the ramifications of the optical physics of light pipes within the full context of his design and objectives.

9.2.1.2 Detailed Design Procedure

9.2.1.2.1 Optomechanical Design (PicoStar™ Variant)

After completing the electrical design and understanding optical interface, the next task is the optomechanical design of the FPCB cutout. Design this cutout in conjunction with the tolerance capabilities of the FPCB manufacturer. Or, conversely, choose the FPCB manufacturer for the capabilities of creating this cutout. A semi-rectangular shape of the cutout, created with a standard FPCB laser, is presented here. There are many alternate approaches with different cost, tolerance, and performance tradeoffs.

An image of the created FPCB with the plus shaped cutout and a rectangular shaped cutout is shown below. The plus shape is a good choice for light collection in both directions with a wider field of view. In case of the rectangular cutout shape, the long (vertical) direction of the cutout has minimal effect on the angular response because any shadows created from the FPCB do not come near the sensor. The long cutout direction defines the axis of rotation with the less restricted field of view. The narrow (horizontal) direction of the cutout, which is limited by the electrical connections to OPT4001, can create shadows that can have a minor impact on the angular response. The narrow cutout direction defines the axis of rotation of the more restricted view. The possibility of shadows are illustrated in Figure 9-6, a cross-sectional diagram showing the OPT4001 device, with the sensing area, so ldered to the FPCB with the cutout. A circular cutout is more restrictive in the field of view casting shadow from all directions of light. TI recommends to take in to account the effect of shadows and impact of this on the field of view of the sensor. The product folder has application notes and tools to help understand these artifacts.

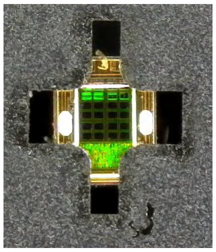


Figure 9-4. Image of FPCB With OPT4001 Mounted, Receiving Light Through the Cutout with a Plus Shape

Figure 9-5. Image of FPCB With OPT4001 Mounted, Receiving Light Through the Cutout with a Rectangular Shape

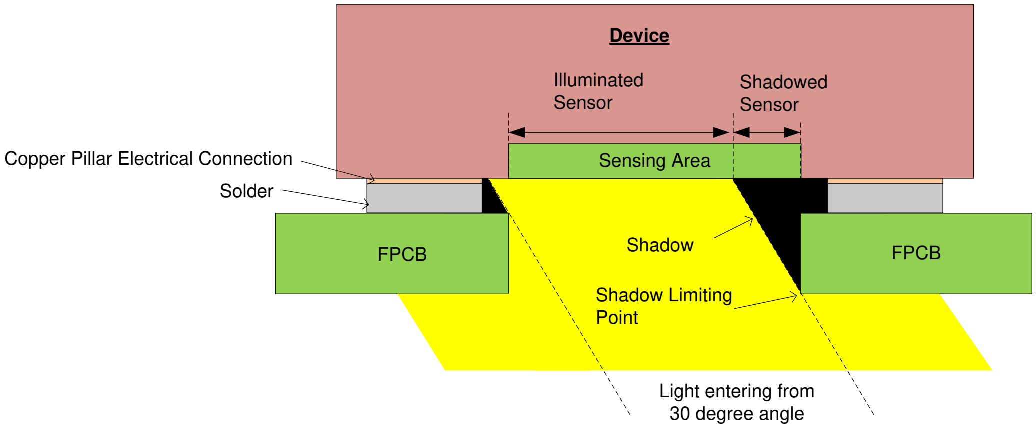


Figure 9-6. Cross-Sectional Diagram of OPT4001 Soldered to an FPCB With a Cutout, Including Light Entering From an Angle

There can be an additional need to put a product casing over the assembly of the device and the FPCB. The window sizing and placement for such an assembly is discussed in more rigorous detail in application report *OPT3001: Ambient Light Sensor Application Guide* (SBEA002).

9.2.1.2.2 Optomechanical Design (SOT-5X3 Variant)

After completing the electrical design, the next task is the optomechanical design. Window sizing and placement is discussed in more rigorous detail in *OPT3001: Ambient Light Sensor Application Guide*.

9.2.1.3 Application Curves (PicoStar™ Variant)

Figure 9-7 and Figure 9-8 show example response curves of the device for a rectangular cut out hole as shown in Figure 9-13. The shape of the cutout affects the overall light collection and the field of view can clearly be seen.

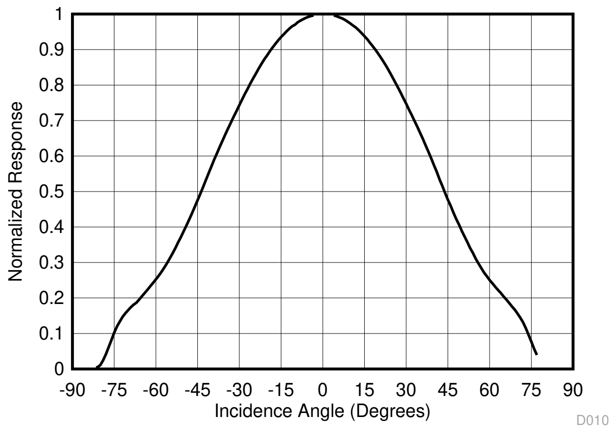


Figure 9-7. Angular Response of this FPCB Design Along the Less-Restricted Rotational Axis

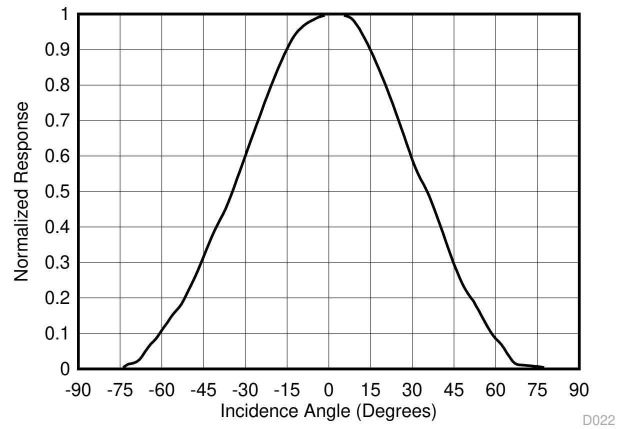


Figure 9-8. Angular Response of this FPCB Design Along the More-Restricted Rotational Axis

9.3 Do's and Don'ts

As with any optical product, take special care when handling the OPT4001. In case of the PicoStar™ variant, the device is a piece of active silicon, without the mechanical protection of an epoxy-like package or other reinforcement. This design allows the device to be as thin as possible. Take extra care to handle the device gently to not crack or break the device. Use a properly-sized vacuum manipulation tool to handle the device.

Generally for both package variants, the optical surface of the device must be kept clean for the best performance, both when prototyping with the device, and during mass production manufacturing procedures. Keep the optical surface clean of fingerprints, dust, and other optical-inhibiting contaminants.

If the optical surface of the device requires cleaning, then use a few gentle brushes with a soft swab of deionized water or isopropyl alcohol. Avoid potentially abrasive cleaning and manipulating tools and excessive force that can scratch the optical surface.

If the OPT4001 performs less than excellent, then inspect the optical surface for dirt, scratches, or other optical artifacts.

9.4 Power Supply Recommendations

Although the OPT4001 has low sensitivity to power-supply issues, good practices are always recommended. For best performance, the device VDD pin must have a stable, low-noise power supply with a 100-nF bypass capacitor close to the device and solid grounding. There are many options for powering the device because of the device low current consumption levels.

9.5 Layout

9.5.1 Layout Guidelines

Before understanding the layout requirement for OPT4001, understanding the placement on the PCB is critical.

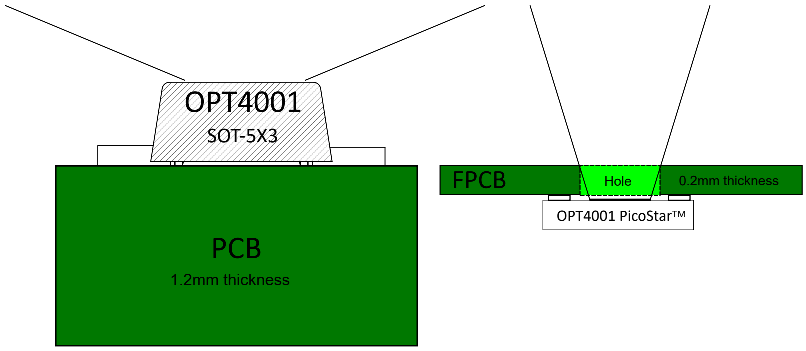


Figure 9-9. Placement Side View of Packages

In case of the SOT-5X3 package variant the device, since the lighting sensitive area and the device pins are on opposite sides of each other, a conventional placement on the PCB makes sure of good light collection. In case of the PicoStar™ variant of the device, since the light sensitive area and the device pins are on the same side, special arrangement as shown in the figure is required to achieve good light collection. Typically a thin flexible PCB with a hole or a cutout centered around the optical area is required for wide angle light collection for the PicoStar™ variant. A regular PCB can be used but the amount of light collected and the field of view of light collection are not very good and generally not recommended. Cut out for the light collection can be of any shape with large enough opening to let ample light fall on the light sensitive area. Figure 9-12 and Figure 9-13 show examples of two such shapes which help maximize light collection. A circular cut out as much larger as the manufacturing allows is also acceptable but can restrict the field of view and reduce the light collection. Tools and documentation are available on TI product folder to estimate the field of view based on the hole size.

Placing the decoupling capacitor close to the device is highly recommended at the same time, note that optically reflective surfaces of components also affect the performance of the design. The three-dimensional geometry of all components and structures around the sensor must be taken into consideration to prevent unexpected results from secondary optical reflections. Placing capacitors and components at a distance of at least twice the height of the component is usually sufficient. The best optical layout is to place all close components on the opposite side of the PCB from the OPT4001. However, this approach is not be practical for the constraints of every design.

The device layout is also critical for good SMT assembly. Two types of land pattern pads can be used for this package: solder mask defined pads (SMD) and non-solder mask defined pads (NSMD). SMD pads have a solder mask opening that is smaller than the metal pads, whereas NSMD has a solder mask opening that is larger than the metal pad. Figure 9-10 illustrates these types of landing-pattern pads. SMD is preferred because SMD provides a more accurate soldering-pad dimension with the trace connections. For further discussion of SMT and PCB recommendations, see the *Soldering and Handling Recommendations*.

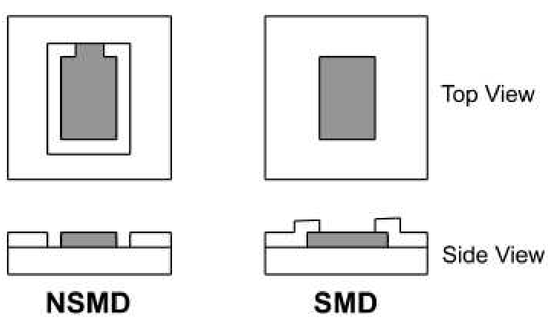


Figure 9-10. Soldermask Defined Pad (SMD) and Non-Soldermask Defined Pad (NSMD)

9.5.2 Layout Example

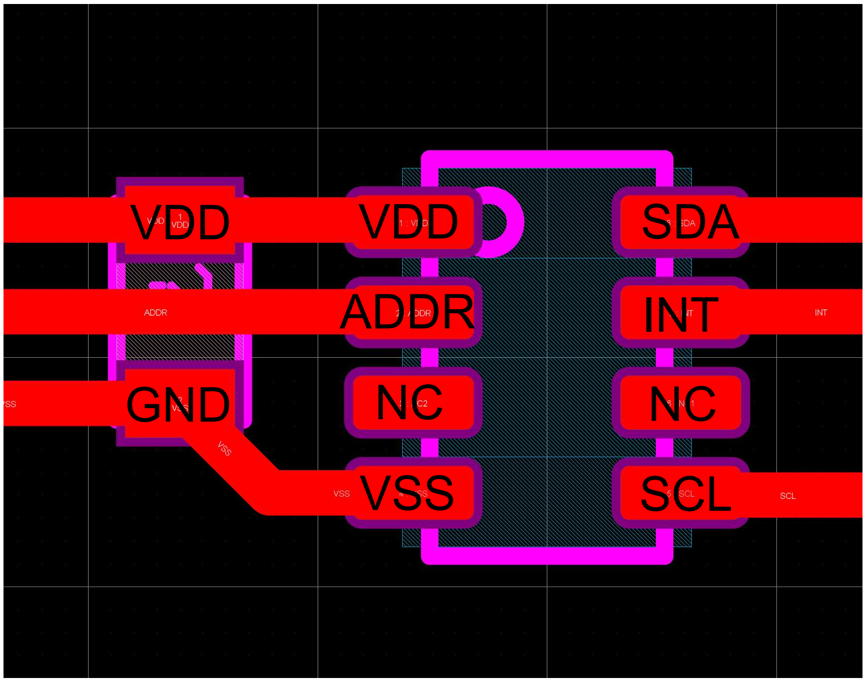


Figure 9-11. Layout Example for SOT-5X3 package

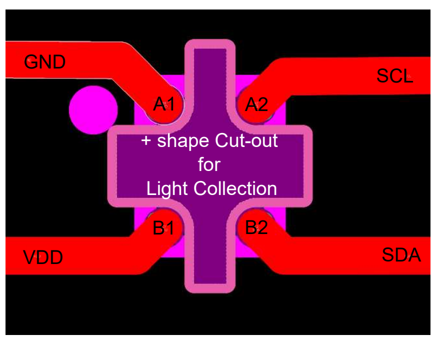


Figure 9-12. Layout Example with a plus shaped cut out

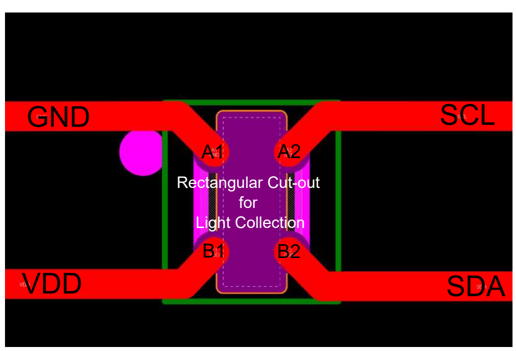


Figure 9-13. Layout Example with a rectangular shaped cut out

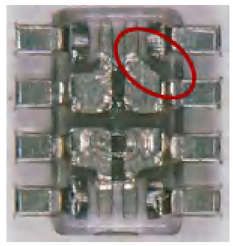
9.5.2.1 Soldering and Handling Recommendations (SOT-5X3 Variant)

The OPT4001 has been qualified for three soldering reflow operations per JEDEC JSTD-020.

Note that excessive heat can discolor the device and affect optical performance.

See application report SLUA271, *QFN/SON PCB Attachment*, for details on soldering thermal profile and other information. If the OPT4001 must be removed from a PCB, discard the device and do not reattach.

As with most optical devices, handle the device with special care to make sure that optical surfaces stay clean and free from damage. See *Section 9.3* for more detailed recommendations. For best optical performance, solder flux and any other possible debris must be cleaned after soldering processes.



Note

The bottom side of the device features an angled feature to denote the PIN 1

Figure 9-14. Identification Feature for PIN 1

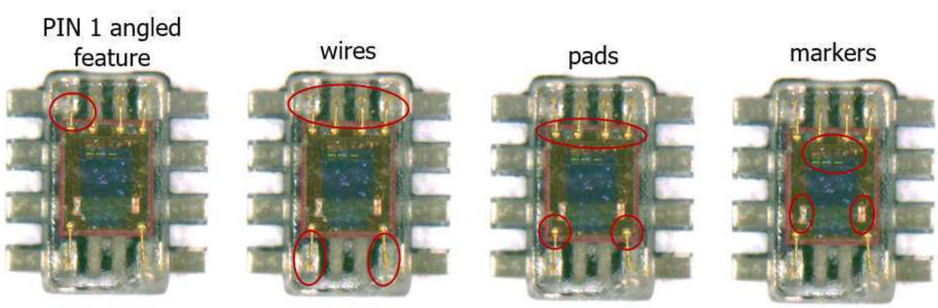


Figure 9-15. Identification Features for PIN 1 on Package

9.5.2.2 Soldering and Handling Recommendations (PicoStar™ Variant)

The OPT4001 is a small device with special soldering and handling considerations. See Section 9.2.1.2.1 for implications of alignment between the device and the cutout area. See Section 9.5.1 for considerations of the soldering pads.

If the OPT4001 must be removed from a PCB, discard the device and do not reattach.

Note that excessive heat can discolor the device and affect optical performance.

As with most optical devices, handle the OPT4001 with special care to make sure that optical surfaces stay clean and free from damage. See *Section 9.3* for more detailed recommendations. For best optical performance, solder flux and any other possible debris must be cleaned after soldering processes.

9.5.2.2.1 Solder Paste

For solder-paste deposition, use a stencil-printing process that involves the transfer of solder paste through predefined apertures with the application of pressure. Stencil parameters, such as aperture area ratio and fabrication process, have a significant impact on paste deposition. Cut the stencil apertures using a laser with an electropolish-fabrication method. Taper the stencil aperture walls by 5° to facilitate paste release. Shifting the solder-paste towards the outside of the device minimizes the possibility of solder getting into the device sensing area. See the mechanical packages attached to the end of this data sheet.

Use solder paste selection type 4 or higher, no-clean, lead-free solder paste. If solder splatters in the reflow process, choose a solder paste with normal- or low-flux contents, or alter the reflow profile per the *Section 9.5.2.2.3*.

9.5.2.2.2 Package Placement

Use a pick-and-place nozzle with a size number larger than 0.6 mm. If the placement method is done by programming the component thickness, then add 0.04 mm to the actual component thickness so that the package sits halfway into the solder paste. If placement is by force, then choose minimum force no larger than 3N to avoid forcing out solder paste, or free falling the package, and to avoid soldering problems such as bridging and solder balling.

9.5.2.2.3 Reflow Profile

Use the profile in Figure 9-16, and adjust if necessary. Use a slow solder reflow ramp rate of 1°C to 1.2°C/s to minimize chances of solder splattering onto the sensing area.

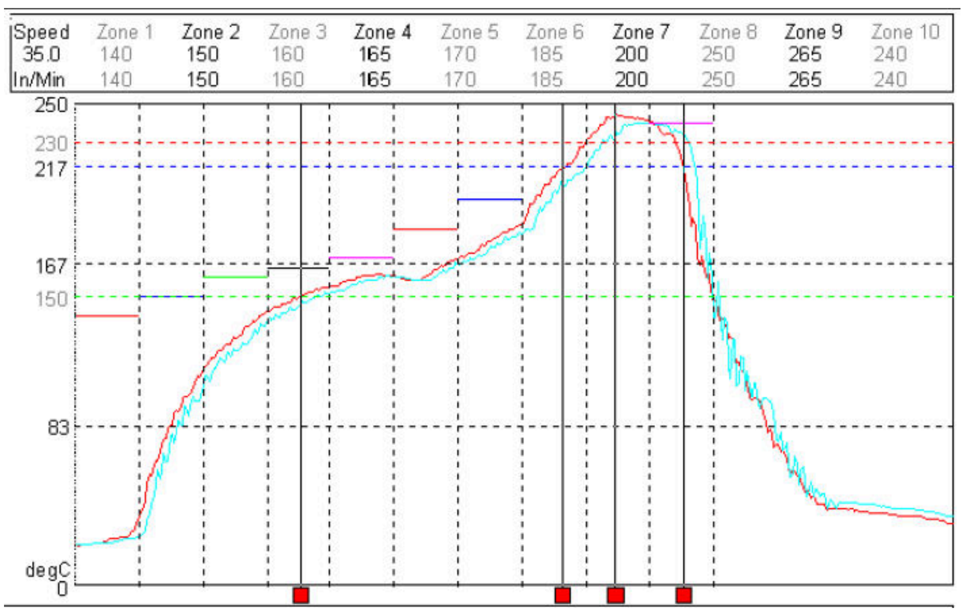


Figure 9-16. Recommended Solder Reflow Temperature Profile

9.5.2.2.4 Special Flexible Printed-Circuit Board (FPCB) Recommendations

Special flexible printed-circuit board (FPCB) design recommendations include:

- Fabricate per IPC-6013.
- Use material of flexible copper clad per IPC 4204/11 (Define polyimide and copper thickness per product application).
- Finish: All exposed copper are electroless Ni immersion gold (ENIG) per IPC 4556.
- Solder mask per IPC SM840.
- Use a laser to create the cutout for light sensing for better accuracy, and to avoid affecting the soldering pad dimension. Other options, such as punched cutouts, are possible. See the *Section 9.2.1.2.1* for further discussion ranging from the implications of the device to cutout region size and alignment. The full design must be considered, including the tolerances.

To assist the handling of the very thin flexible circuit, design and fabricate a fixture to hold the flexible circuit through the paste-printing, pick-and-place, and reflow processes. Contact the factory for examples of such fixtures.

9.5.2.2.5 Rework Process

If the device must be removed from a PCB, discard the device and do not reattach. To remove the package from the PCB/Flexi cable, heat the solder joints above liquidus temperature. Bake the board at 125°C for 4 hours prior to rework to remove moisture that may crack the PCB or causing delamination. Use a thermal heating profile to remove a package that is close to the profile that mounts the package. Clean the site to remove any excess solder and residue to prepare for installing a new package. Use a mini stencil (localized stencil) to apply solder paste to the land pattern. In case a mini stencil cannot be used because of spacing or other reasons, apply solder paste on the package pads directly, then mount, and reflow.

10 Device and Documentation Support

10.1 Documentation Support

10.1.1 Related Documentation

For related documentation see the following:

- *OPT3001: Ambient Light Sensor Application Guide* (SBEA002)
- *OPT4001EVM User's Guide* (SBOU278)
- *QFN/SON PCB Attachment Application Report* (SLUA271)

10.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

10.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

10.4 Trademarks

PicoStar™, Picostar™, and TI E2E™ are trademarks of Texas Instruments.
All trademarks are the property of their respective owners.

10.5 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

10.6 Glossary

TI Glossary This glossary lists and explains terms, acronyms, and definitions.

11 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.