ABSTRACT

This application note describes a new method of mounting TMP007 WCSP die on the printed-circuit board (PCB). The advantages of the new method are described and mounting recommendations are provided. All of the following recommendations and conclusions are also true for TMP006 parts.

Contents

1 Standard Mounting Description ................................................................. 2
2 The Through-Hole Mounting Method.......................................................... 3
3 Example of Object Measurements ............................................................. 8
4 Conclusion ............................................................................................... 8
1 Standard Mounting Description

According to the description provided in the product data sheet, the WCSP die is mounted on the PCB surface and is looking to the measured object through the die back side. The silicon transparency to the infrared (IR) radiation is used here. The IR beam is traveling through 0.3-mm thick die body and reaches the chain of thermocouples located in the center of the die’s opposite surface. See Figure 1.

![Diagram of TMP007 Die Mounting on PCB](image)

Figure 1. TMP007 Die Mounting on PCB According to the Data Sheet’s Current Recommendations

The main problems of the standard method of die mounting are described in the following sections.

1.1 Air Flow Noise

The TMP007 IR sensor thermocouples are hung above silicon surface and therefore are very sensitive to air movement. If the air flow changes due to, for example, fan switching inside the user device, in most cases, it shifts the measurements results and the calibration procedure should be repeated. Air flow also brings a lot of noise into the measurements and limits the device precision. For example, if the difference between the measured object temperature and temperature of the PCB where the TMP007 is mounted is greater than 60 degrees, then the convection air flow starts to bring so much noise into the measurements that special design efforts are needed.

1.2 Signal Weakening

Silicon is a semitransparent material for IR radiation; therefore, the IR energy is weakened 4-5 times on its way from the die’s back side to the IR sensor located in the center of the die’s front side. The weaker IR signal produces a smaller sensor reaction and a smaller signal to noise ratio. This limits the distance to the measuring object and also reduces measurements precision.

1.3 Field of View (FOV)

The standard device placement produces a very wide field of view. On 50% of the sensor maximal level, the FOV is 90 degrees; but on 25% level it is around 100 degrees. This means that until the measuring object is very big and is placed on a very close distance, approximately 10 to 30 mm, the TMP007 is receiving the IR signals from all other objects placed in front of the die. This makes the measuring procedure very unstable. To solve this problem, the user has to put the object closer to the die or to build some FOV limitation barrier around the die. It can be, for example, a metal cap soldered around the device with a hole in its center. See Figure 2.
1.4 Heating from the Object

If the temperature of the measured object is significantly different from the TMP007 temperature, and die is placed close to the object, then the object starts to heat or cool the exposed TMP007 part. The local temperature change during the object temperature measurements significantly affects the result precision. It can be partially compensated by using the transient correction feature of the device. However the transient correction ability is very limited and also makes the calibration process more complicated.

1.5 Device Protection

The die location on the board surface facing external object makes the TMP007 part very vulnerable to environment challenges. The dust, moisture, dirt, and/or hand touches can affect the IR sensor precision or even cause damage to the device.

2 The Through-Hole Mounting Method

The main difference between the standard method and through-hole method is that the die is looking to the object through the small via (hole) located underneath the center of the die. See Figure 3.
2.1 Advantages

Comparing to the standard mounting, the through-hole mounting makes the following differences:

2.1.1 Air Flow Noise

Because the back of the die is now covered with the compound or can be protected in any other way, the part becomes insensitive to air flow.

2.1.2 Signal Strength

In this case the IR signal arrives through the via directly to the IR sensor center and affects it directly without being weakened by die silicon travel. By regulating the via diameter it is possible to get a situation where the IR beam covers only the thermocouples hot junction and leaving the cold junctions in a shade. All this together increases the sensor sensitivity four plus times and rises the signal/noise ratio.

2.1.3 Field of View

The FOV also becomes narrower by 20 to 30 degrees, depending of the via hole diameter and the board thickness. By changing these two board parameters, the user now has a tool to regulate the FOV.

2.1.4 Heating from Measured Object

The TMP007 now is located on the board side opposite to the measured object. It gives much better options to thermally isolate the device from upcoming heat or cold from the measuring object. It is possible to put heat reflection film on PCB surface exposed to the object or even put some radiators on the PCB die side to prevent fast die temperature change. The improved die temperature stability makes measurement more precise and in some case reduces the local temperature operation range which can also lead to a reduced number of calibration points.
2.1.5 Device Protection

In the suggested mounting method, the device is located in a practically sealed compartment and is immune to dust, moisture, and hand touching. The guiding via end looking to the object can be covered with an IR transparent film, like polypropylene. This protects the via from getting clogged by dust and allows the user to wipe off the dust absorbed on the board without the risk of damaging the TMP007 die.

2.1.6 Part-to-Part Variation

Due to technological restriction, the manufacturing trimming of TMP007 is performed from the parts front (sensor’s) side of the die. In the case of standard mounting, the IR signal is coming from the part’s back side which is not involved in the trimming process. This leads to the conclusion that through-hole mounting should have less part to part variation because in this case the variations of die thickness, silicon IR transparency, back side surface condition are all irrelevant and, therefore, the part to part variation in IR sensitivity should be less. It means that in the case of using common calibration coefficients, part-to-part variation should also be less, until there is no vias wall quality variation between the boards. For the 27 parts mounted through-hole over 16-mil vias, the object temperature measurements precision remained inside the ±2°C corridor. The object temperature changed from +20°C to +50°C, but the dies temperature remained at +21°C at all times. The same common calibration coefficients were loaded into all parts. The distance to the object was 55 mm, the board thickness was 90 mil, and supply voltage was 3.3 V.

2.2 Signal Strength Versus Board Thickness and Via Diameter

The signal strength is proportional to via diameter and the signal is weaker if the PCB is thicker. See Figure 4. The via maximal diameter is limited to 20 mil by the available space between WCSP balls mounting pads. However, as you can see in Figure 4, the via with a diameter bigger than 16 mil provides weaker IR sensors response. The reason for this is that the IR beam diameter coming through the via becomes bigger than thermocouples’ hot junctions area on the die (13 mil × 13 mil) and the radiation starts to heat the thermocouples cold junctions.

Figure 4. TMP007 IR Sensor Response Depends on Via Diameter and Board Thickness

2.3 FOV Versus Board Thickness and Via Diameter

The common expectation is that through-hole FOV will follow the simple geometry shown in Figure 5.
In reality, the amount of IR going directly through the via without reflection is very small. A significant amount of IR enters from the side directions, and by reflecting multiple times from the via golden walls, the IR is channeled to the sensor. Therefore, the real FOV is much wider than the expected 21 degrees, and also explains why a non-plated hole cannot work as the IR tunnel. Figure 6 shows the FOV for some real board cases.

As you can see in Figure 6, the FOV difference between thinner via and thicker board case and the opposite case (with thicker via and thinner board) is only 20 degrees. The significant reducing the via diameter to get narrower FOV is not a very good option because it decreases the signal strength and, more importantly, makes a system more vulnerable to via quality: the hole diameter variation from board to board and how clear is the via opening from any PCB technology residual.

Increasing the PCB board thickness reduces the FOV more significant, but thick boards are not convenient for use in many applications. Another options to reduce FOV are building some view restrictions around the guiding via entrance, or removing the reflective plating in the top part of the via. By drilling the upper part of 16-mil via with 20-mil bit to half of the board thickness, the FOV can be reduced from 65 degrees to 37 degrees (on 50% signal level and board thickness of 90 mil). Note that this is closer to theoretical FOV without the reflections. Because there present multiple reflections from the via internal walls, the quality of the surface affects the amount of IR energy coming to the sensor. This is especially important in case of using common calibration coefficients for multiple parts. TI recommends monitoring the quality of the via walls.
2.4 The Layout Recommendations

The main layout goal in a standard device mounting is to channel away any extra heat which is absorbed by the PCB surface exposed to the object. This heated board surface under the die radiates to the IR sensor located only 0.35 mm above the board and affects measurement precision. Therefore, all efforts were taken to guard the device from this extra heat coming from around. TI recommends having a copper ring around the die and have 8 vias with tasks to channel the heat to the opposite side of the board.

In the through-hole case, when the device is placed on the board side opposite to the object, the goal is different. Now the goal is to create a maximal temperature stable environment to the TMP007 device. This includes providing maximal thermal resistance between two sides of the board. Therefore, all unneeded vias around the die should be avoided; the thicker the board the better, and any heat reflecting and dissipating surfaces on both sides of the board are working for better device precision. Some additional recommendations are described in the next chapter.

2.5 Measuring Extreme Temperatures Objects

Measuring a very cold or very hot object from a close distance has some specific. In the through-hole method, the part is protected from the convection air flow by its location on the opposite side of the board and the die is also covered by some compound, metal, or rubber cap. The strong IR signal coming from the close located measured object, due to increased device sensitivity, can easily exceeds the sensor voltage range ±5.12 mV. On the first view the easiest way to reduce the signal strength is to use the via with smaller diameter. But a small via with a diameter like 8 to 10 mil have unpredictable real hole diameter and easily could be clogged during the PCB manufacturing. The more practical way to bring a signal into the desired range is to cover the via with some film with limited IR transparency. One of the good candidates to this role is the kapton 1-mil sticky tape. It reduces the IR signal strength about 10 times and puts the IR sensor voltage back into the range. There is another advantage of using this high temperature film. It protects the via from clogging by the environmental dust. See Section 2.5.1.

2.5.1 The TMP007 Board Prepared to Work With High Temperature +300°C Object

![Figure 7. The Board Side Which Will Be Exposed to the Object. There is a Guiding 16-mil Via in the Center.](image1)

![Figure 8. 1-mil Sticky Kapton Tape Glued to the Board](image2)

![Figure 9. The Board is Covered With Sticky Aluminum Foil to Reflect IR from the Object.](image3)

![Figure 10. The Opposite Side of the Board. Here the TMP007 and Bypass Capacitor Will Be Soldered.](image4)
The simplest way to protect the board from upcoming heat is to reflect incoming IR back to the environment. This can be done by covering the side of the board which is looking to the object by the sticky aluminum foil. The more advanced way is to make a copper polygon which is plated and is located around the guiding via and is not covered with a PCB solder mask. This will work as an IR mirror and reduces the TMP007 local temperature change.

3 Example of Object Measurements

In this example, the measured object was located at a distance of 55 mm from the board with through-hole mounted TMP007. The board is located vertically and the board's surface exposed to the object was covered with aluminum foil. The board thickness is 90 mil and the guiding via diameter is 16 mil. The part supply voltage was 3.3 V and sampling period was 1 sec. The TMP007 temperature was controlled by the external tool. The calibration procedure and coefficients calculation was performed individually for this device. See Figure 12.

As you can see here the die temperature range is wider than DS guaranteed range 0°C…+60°C. The object temperature range is wider than data sheet ensured range –15°C to +85°C. Part easily satisfies the guaranteed precision of ±5°C.

4 Conclusion

The suggested TMP007 and TMP006 through-hole mounting method solves many IR sensors application problems. The measurement precision, measurement stability, object temperature range, local temperature range are significantly improved and open new possibilities for the device. Any customer application is unique and therefore system settings should be chosen carefully.
IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have not been so designated is solely at the Buyer’s risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio</td>
<td><a href="http://www.ti.com/audio">www.ti.com/audio</a></td>
</tr>
<tr>
<td>Amplifiers</td>
<td>amplifier.ti.com</td>
</tr>
<tr>
<td>Data Converters</td>
<td>dataconverter.ti.com</td>
</tr>
<tr>
<td>DLP® Products</td>
<td><a href="http://www.dlp.com">www.dlp.com</a></td>
</tr>
<tr>
<td>DSP</td>
<td>dsp.ti.com</td>
</tr>
<tr>
<td>Clocks and Timers</td>
<td><a href="http://www.ti.com/clocks">www.ti.com/clocks</a></td>
</tr>
<tr>
<td>Interface</td>
<td>interface.ti.com</td>
</tr>
<tr>
<td>Logic</td>
<td>logic.ti.com</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>power.ti.com</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>microcontroller.ti.com</td>
</tr>
<tr>
<td>RFID</td>
<td><a href="http://www.ti-rfid.com">www.ti-rfid.com</a></td>
</tr>
<tr>
<td>OMAP Applications Processors</td>
<td><a href="http://www.ti.com/omap">www.ti.com/omap</a></td>
</tr>
<tr>
<td>Wireless Connectivity</td>
<td><a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a></td>
</tr>
<tr>
<td></td>
<td>TI E2E Community      e2e.ti.com</td>
</tr>
</tbody>
</table>

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2016, Texas Instruments Incorporated