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Opto Semiconductors

Measuring the temperature profile during the reflow solder process

Application Note

Valid for:
SMD LEDs from OSRAM Opto Semiconductors

Abstract

With reference to the application note "Further details on lead-free reflow soldering of LEDs" the present application note provides details and recommendations for the measuring of the temperature profile during the lead-free reflow solder process. Besides general information on thermocouples, the critical selection of suitable measuring points is described as well as different possibilities for the attachment are introduced.

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Table of contents

A. Introduction

With introduction of the RoHS directive, increased attention must be paid to the soldering equipment and particularly on the processing due to the reduced process window in the lead-free manufacturing processes. Since the maximum load of the SMD devices can be reached or exceeded very fast during the lead-free process, the exact knowledge of the thermal conditions is essential for the generation of suitable soldering processes. Because of this and for the evaluation of a potential impact on the devices, the real temperatures at critical points on the PCB and on sensitive devices should be measured accurately during the soldering process to receive individual temperature profiles of the complete soldering procedure.

In the following some references and recommendations are given for the collection of the temperature profile.

B. Measuring the temperature profile

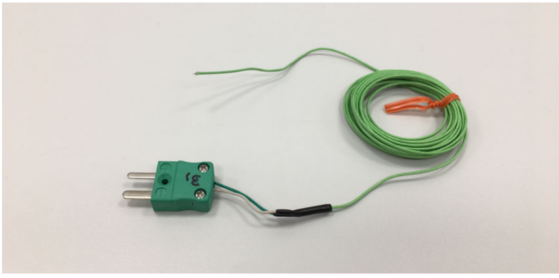
For accurate temperature monitoring at critical points of the printed circuit board during the soldering process, thermocouples are used in industry.

In their simplest form, thermocouples consist of two wires of different materials that are welded together at one end. The measurement determines the temperature-dependent contact voltage that builds up between the wires (thermal voltage), and assigns it to the appropriate temperature value (see application note “Temperature measurement with thermocouples”).

Thermocouples

For temperature ranges up to 400 °C, type K thermocouples made of nickel-chromium (Chromel) and nickel (Alumel) are generally used. Their range of use for profiling the soldering process is, in principle, only limited by the temperature resistance of the insulation material used in the wires. Figure 1 shows an example of a type K thermocouple.

Figure 1: Example of a type K thermocouple



From the variety of thermocouples, the most commonly sensors used have wire diameters (AWG – American Wire Gauge) of size AWG 30 to AWG 40 for the monitoring of the dynamic temperature behavior under temperature cycling and reflow conditions.

In terms of accuracy, however, thermocouples with wire diameters AWG 36 to AWG 40 are recommended, especially if the components are small and the wire diameter, proportional to the mass of the package, can cause significant heat reduction.

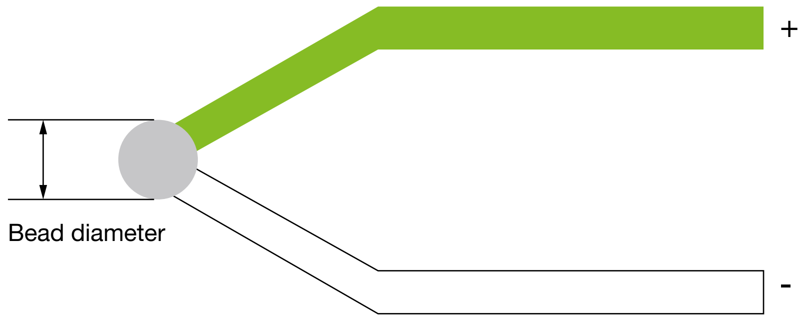
Response time of thermocouples

To record the dynamic changes in temperature accurately and in detail during the cycle, thermocouples with correspondingly short response times are needed, especially in measurements at miniature components with rapid temperature changes.

The response time of thermocouples is mainly influenced by the size of the weld bead and by the conducting wire (material), including the attachment method. The response time is proportional to the surface of the active connection and the diameter of the wire from which the thermocouple was made. This means, the smaller the weld bead and the thinner the wire, the shorter the response time, i.e. the thermocouple responds faster.

For a precise measurement of the temperatures during a reflow soldering process, the commonly used thermocouples (less than or equal to AWG 30) have a sufficiently fast response time for mounting on the surface of the printed circuit board or the components.

Figure 2: Schematic structure of a thermocouple (color code type K)



In terms of cost, size, and strength thermo-couples with wire diameters from AWG 30 to 36 ultimately represent a good compromise. Thinner versions are considerably more likely to break, while with thicker elements the probability increases that the measurement point (weld bead) is greater than the component or the actual point of attachment.

Table 1: Suitable thermocouples for temperature monitoring during reflow soldering

Designation	**Datapaq PA0210/ PA0215 fast response**	**Datapaq PA1683 fine wire**	**OMEGA SRTC**
Type	Type K	Type K	Type K
Isolation	PTFE or glass fiber	Glass fiber	PTFE or glass fiber
Accuracy	± 0.4 % or ± 1.1 °C	± 0.4 % or ± 1.5 °C	± 1.5 °C
Length	800 nm	500 nm	1000 nm
Conductor diameter	0.2 mm / 32 AWG	0.12 mm / 36AWG	0.25 / 30 AWG
Temperature	max. 265 °C	max. 265 °C	max. 265 °C / max. 480 °C

Selection of the temperature measurement points

In the past, with lead-containing soldering processes no attention must be paid to the selection of appropriate measurement points for temperature monitoring, since the relatively large process window offered a sufficient distance to the damage limit of the components. In general, only the areas that were assumed to be the hottest and coldest points on the printed circuit board were used for profiling. The fixing of thermocouples to corresponding solder pads was used primarily to determine whether the thermal profile was consistent across the entire product.

For lead-free solder processes, the selection of the temperature measuring points is significantly more critical and relevant to components, as the process moves in close proximity to the components, with little room to prevent damage. To avoid damage to the components, it is of utmost importance that all critical or sensitive components, such as LEDs, miniature components, etc. are identified in advance and that additional temperature measurement is made on these components. These component-specific temperature profiles are important because the stress occurring during the heating and cooling phases at the SMD housing can only be estimated through knowledge of the prevailing temperature gradients on the component. In this way individual reference points can be obtained and the real conditions on the critical components can be recorded, making possible a comparison of different oven settings and thus profile curves. For further information on the measuring point of LEDs please refer to the application note "The thermal measurement point of LEDs".

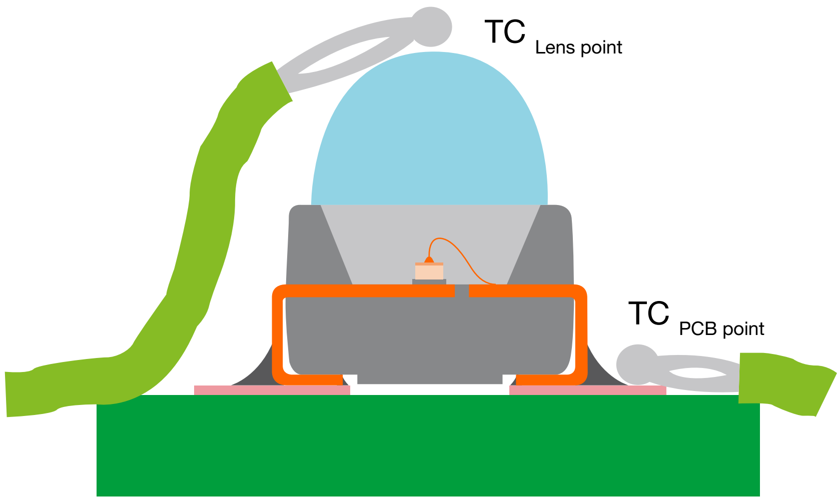
However, the identification of critical components and definition of measurement points represent only the first step; of crucial importance in this context is the selection of the measurement point on the component itself.

In the JEDEC J-STD 020D it is specified that all temperatures refer to the center of the package, and should be measured on the component surface that faces upward during the reflow soldering process.

OSRAM Opto Semiconductors follows this guideline, and all its temperatures statements in the classification or in the reflow profile refer to the center of the package, which is measured at the top of the component.

For SMD LEDs, especially for LEDs with lenses, the choice of two measuring points or places is recommended, one at the top of the component (lens) and the other at the solder pad on the printed circuit board.

Figure 3: Temperature measuring points for the Power TOPLED with lens



C. Attachment of thermocouples

The most important factor/point to obtain meaningful results in the measurement of thermal profiles, is to ensure a suitable attachment and a good surface contact of the thermocouple during the temperature measurement. In general, there are various methods to attach thermocouples to printed circuit boards, solder pads, or components, such as:

- High-temperature (HT) solder
- Aluminum tape
- Polyimide tape (Kapton®)
- Conductive / non-conductive epoxy

High-temperature solder

The attachment of the thermocouple with high-temperature solder is considered an industry standard, as it ensures excellent repeatability and a very strong connection.

Figure 4: Attachment using high-temperature solder

However, the fairly complicated and elaborate workability of high-temperature solder can be a drawback. This is particularly evident in the fact that the work requires a special HT soldering iron to be used, and that it can only be used on metalized surfaces. It also must be taken into account that thermocouples (e.g. type K) exhibit bad wetting behavior, and soldering ultimately always results in the destruction of the test product. In addition, if too much solder is applied, the heat capacity of the thermocouple thus increases, causing an incorrect temperature measurement. The thermocouples must therefore be attached with a minimum of solder.

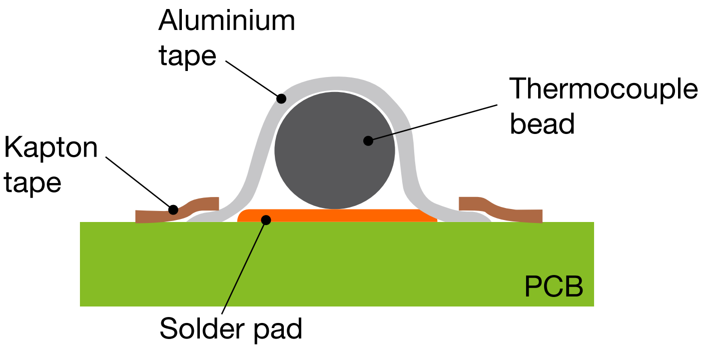
Usually, solders with 90 % lead and a melting point of above 290 °C are used. Silver-tin compounds are also in use.

Aluminum tape in combination with polyimide tape

Another method, also known as window panning, is attachment with aluminum tape in combination with polyimide tape.

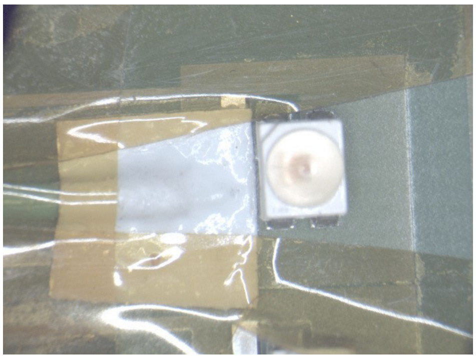
In addition to good a contact with the measuring point, the aluminum band provides good heat transfer and enables a rapid temperature measurement. The polyimide is used for the actual temperature-stable attachment, where it should be noted that the polyimide tape does not cover the area with the thermocouple tip.

Figure 5: Attachment with aluminum and polyimide tape



It is also not recommended to use the polyimide tape by itself, because no consistent contact between the measuring point and thermocouple is achieved, and the adhesive force is limited.

Figure 6: Example of temperature measurement on the solder pad of an LED, attachment with aluminum and polymide tape



The aluminum tape (e.g. KIC-Thermal Alu Tape) must be cut to a size of around 5 mm x 5 mm for the attachment, so that the tip of the thermocouple can be placed on the selected solder pad of the printed circuit board. Broad strips of polyimide tape may then be attached to the edge of the aluminum strip for additional fixation and additionally securing the thermocouple cable.

The combination is a simple, inexpensive and non-destructive way to attach thermo-couples to printed circuit boards for profile acquisition. Their secure connection with simultaneous excellent thermal conductivity ability has been demonstrated in industry studies with different measuring equipment and thermocouple suppliers [4].

OSRAM Opto Semiconductors therefore uses this system as its preferred attachment technology, to the extent that it can be used on the printed circuit board being investigated.

Epoxy resin — conductive or non-conductive

Another widespread option for mounting is epoxy adhesives, where both types, thermally conductive and non-conductive adhesives, are used. These are much easier to handle and process than the high-temperature solders. The adhesives are typically used when thermocouples should be applied to non-solderable surfaces such as plastic or ceramic components.

Before using an epoxy, the properties such as the specified temperature range and heating requirements of the material should be checked.

Quick-setting epoxies are usually classified only for temperature ranges below 200 °C, and therefore crumble during the soldering process. Special high-temperature resins, on the other hand, require a baking time of several hours at elevated temperatures.

When working with the adhesive, make sure to keep the adhesive surface as thin as possible, or to use only as much adhesive that heat conduction between the body surface and thermocouple is possible.

For example, OSRAM Opto Semiconductors uses the epoxy resin LOCTITE 3609 to attach the thermocouples. This is suitable for temperatures up to 260 °C, and has a baking time of 90 seconds at a temperature of 150 °C.

Thermocouple attachment on solder pads

In general, two methods can be used for the attachment of thermocouples to the surfaces of solder pads: high-temperature solder and aluminum tape.

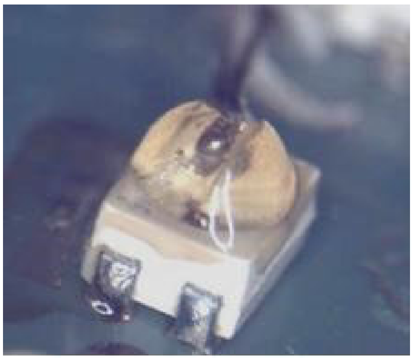
If there is sufficient space on the printed circuit board around the solder pad, the method with the aluminum tape is preferred, because it is both easier and faster to use and can be removed without damage to the board.

Attaching thermocouples to LEDs with lenses

If the measuring point is on the top side of the package or on the lens of LEDs, only epoxy adhesive can typically be used to attach the thermocouples. Other methods are of very limited suitability for reasons of space or temperature.

In accordance with JEDEC JEP140 (“Beaded Thermocouple Temperature Measurement of Semiconductor Packages”), temperatures of package can be obtained by drilling a hole, barely larger than the thermocouple tip, into the package. In contrast, for components with a thin package, attaching the thermocouple on the package surface should be sufficient to measure the temperature.

Figure 7: Attaching a thermocouple to an LED lens



To measure at the lens of the LED, the following approach has proved its worth at OSRAM Opto Semiconductors:

1. The LED should be soldered to the printed circuit board with a high-temperature solder (e.g Pb90Sn, with a melting temperature of ~ 290 °C). This prevents the LED from lifting off the printed circuit board during the reflow process due to the internal stress of the thermocouple. Alternatively, the LED can also be additionally attached with an SMT adhesive when using lead-free solder.
2. A small opening should be made in the lens in which the thermocouple tip can be fixed.
3. Attach the thermocouple tip with clear epoxy adhesive.
4. Bake the adhesive at the lowest possible temperature.
5. Additional fixing of the thermocouple wiring with polymide tape.

Data acquisition and recording

The data acquisition and recording during the soldering process is generally performed with a data acquisition system or data recorder that also passes through the oven. The system should be able to process the resulting data fast enough, and have a sufficient number of recording channels to obtain the necessary profile data along the process calibration points. Similarly, the data recorder should include the required thermometric calibration points, such as a temperature reference point for thermocouple measurements.

OSRAM Opto Semiconductors itself uses the DQA 1860 DATAPAQ data recorder for profile acquisition, for example. In Figure 8, the most important parameters for this are listed.

Figure 8: DATAPAQ DQ1860 data recorder

DATAPAQ DQ1860

Sampling Intervall:	0.05 seconds to 10 minutes
Accuracy:	± 0.5 °C
Resolution:	0.1 °C
Maximum internal operating temperature:	85 °C
Temperature range:	- 200 °C to 1,370 °C
Memory:	18,000 readings per channel
Data collection start:	Start / stop buttons, time or temperature trigger
Battery:	NiMH rechargeable
Thermocouples:	Type K

Summary

The increased requirements of the lead-free reflow solder process need to some extend unitary rules for the temperature respectively profile measurement and in this connection compliance with appropriate guidelines, which are:

- Measuring method with thermocouples
- Thermocouple type and wire diameter (type K, AWG 30 – 40)
- Measuring location on the board (homogeneity across the entire module)
- Sensor placement on critical components (component top side)
- Method of thermocouple connection (HT solder, aluminum tape, epoxy)

Suitable equipment providing an optimized and controlled soldering process can be achieved easier substantially. This is not only a prerequisite for the functional efficiency of a board, but also significantly influences the quality of the solder joint, and thus its reliability.

D. Literature

[1] JEDEC J-STD 020 D.1

[2] JEDEC Publication No 140

[3] TC Farb Tabelle

[4] Cameron Sinohui, A Copmparison of Methodes for Attaching Thermocouples to PCB for Thermal Profiling, KIC Thermal Profiling

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