TECHNICAL
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Environmental testing –

Part 3-12:
Supporting documentation and guidance – Method to evaluate a possible lead-free solder reflow temperature profile

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ENVIRONMENTAL TESTING –

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FOREWORD

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IEC 60068-3-12, which is a technical report, has been prepared by IEC technical committee 91: Electronics assembly technology.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
91/601A/DTR	91/636A/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

A list of all the parts in the IEC 60068 series, under the general title *Environmental testing*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

ENVIRONMENTAL TESTING –

Part 3-12: Supporting documentation and guidance – Method to evaluate a possible lead-free solder reflow temperature profile

1 Scope

This part of IEC 60068 serves as a Technical Report and presents two approaches for establishing a possible temperature profile for a lead-free reflow soldering process using SnAgCu solder paste.

This process covers a great variety of electronic products, including a large range of package sizes (molded active electronic components, passive components and electromechanical components).

Study A addresses requirements needed in the production of automotive electronic control units (ECU). These requirements include, but are not limited to, measurement and production tolerances.

Study B represents consumer electronics products and includes reflow oven capability, board design and package sizes.

2 Basics

The process temperature for SnPb solder paste has a wide margin due to the liquid temperature of the solder alloy. During reflow soldering, temperature differences between components exist but are not critical. The process temperature of SnAgCu solder paste is about 20 K to 30 K higher than SnPb solder paste. Furthermore the temperature difference between components (ΔT) becomes wider and sometimes heat resistance temperature of components is exceeded.

To avoid soldering failures which could be very harmful in safety related applications and also generate higher failure costs, the capability of the soldering process is very important. A compromise between the temperature requirements of highly reliable solder joints and the limited solder heat resistance of the electronic devices has to be found. In addition, the different aspects of mass production have to be covered. To achieve a reliable solder joint, the conventional reflow soldering process with eutectic SnPb solder paste is usually performed at a minimum peak temperature of about 203 °C at the coldest solder joint (i.e. at least 20 K above the liquid temperature of SnPb T_{liquid} = 183 °C).

The selected lead-free solder is SnAgCu with a melting point at around T_{liquid} = 217 °C [1] [1]. It is a generally preferred material for lead-free reflow and wave soldering in mass production [2]. Using SnAgCu solder paste, it is not possible to solder the coldest solder joints at least 20 K above the liquid temperature (T_{liquid} = 217 °C), which would result in minimum temperatures of 237 °C. When the coldest solder joint is 237 °C, the temperature spread between small and large devices, small semiconductor, and passive components, as well as the printed circuit board (PCB), will be so large that the devices will not survive the heat impact. Despite the aim to achieve a relatively low temperature at the coldest solder joint, the reliability of the solder joint has to be assured (for instance, for safety related applications in automotive industry).

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[1] References in square brackets refer to the bibliography.

To reach this target in Study A, the temperature at the coldest solder joint is taken to be T_{min} = 230 °C, minimum for 20 s, which is just 13 K above the melting temperature. This corresponds to 1 s at 233 °C resulting from the peak shape (see Figure 1). From a physical point of view, the risk of insufficient solder wetting during mass production is significantly higher if the solder joint temperature is lower as the above mentioned 230 °C. In addition, new lead-free termination finishes (like tin layers with a post bake process or very thin NiPdAu finishes) are known to wet poorer than conventional SnPb pin finishes.

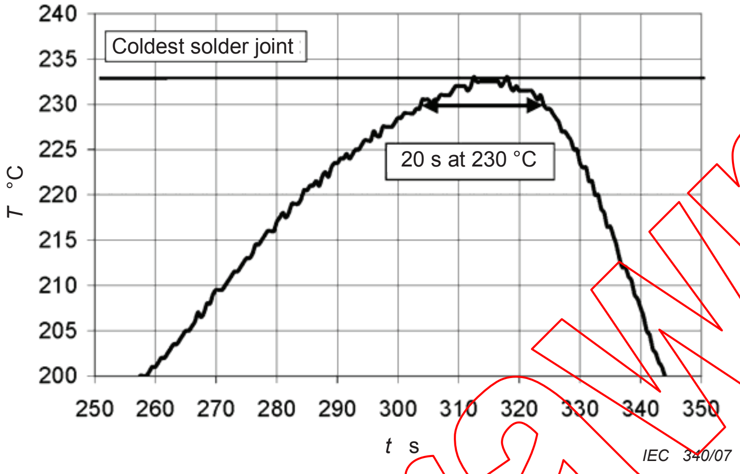

Figure 1 – Curve shape for a peak temperature of at least 20 s at 230 °C and 1 s at 233 °C

The experiments had been performed under mass production conditions (850 mm/min) on the newest oven equipment, i.e. multiple heating zones, full convection, N_2 atmosphere. Seven ovens from European and American manufacturers were evaluated in 2003. Only four of the seven ovens were able to fulfill the given requirements concerning the temperature spread. These were the ovens which were used in the study A.

If the components use selected material regardless of the cost, it may solve the heat resistance issue but it might not be feasible for industries. To overcome this problem, two approaches are used to come to a compromise with reasonable cost. One is from components by improving heat resistance and the other one from assembly including board design (alignment of components, board size, etc.) and reflow oven capability (heating method, number of heating zone, etc.) by reducing ΔT.

3 Boards under investigation

3.1 Test board approach

For the experiment in Study A, a special test PCB was designed. Polyimide resin with a glass transition temperature of T_g = 260 °C was used as base material for the PCB. The test board can represent the whole automotive ECU spectrum. The largest temperature difference (ΔT) between the coldest solder joint and the hottest point existing on this printed circuit assembly (PCA) spectrum is reflected on this test board (ΔT can be even larger for even more complex PCAs). The coldest solder joint was represented by a defined thermal mass. Its temperature behavior was correlated with the temperatures of the coldest solder joints on serial boards.

3.2 Production board approach

For Study B, PCB and reflow oven are taken from actual production.

4 Temperature tolerances

4.1 Temperature tolerances in Study A

For tolerances during temperature profiling, different systematic failures shall be considered. First of all, there is the failure during temperature measurement itself. The measurement was performed in the centre on top of the packages with a well defined and repeatable preparation technique. Nevertheless, the failure due to preparation had to be fixed within ±1,0 K. In addition, the thermocouple (NiCrNi), together with the evaluation unit has an accuracy of ±1,5 K for pre-selected thermocouples. According to IEC 60584-2 the NiCrNi thermocouples, class K, tolerance class 1 are specified with a tolerance of ±1,5 K for just the thermocouple itself without the measurement unit. Based on suppliers indication and own measurements, the furnace tolerance based on furnace load is ±0,5 K and the furnace tolerance for long term stability is ±2,5 K. The long term stability of the furnaces should be improved in the future.

- Thermocouple with measurement unit: ±1,5 K
- Preparation: ±1,0 K
- Furnace load: ±0,5 K
- Long term stability of furnace: ±2,5 K

Because these errors are independent, the Gaussian error propagation can be applied, which results in a total tolerance of ±3,0 K, due to measurement errors and variations in mass production. The tolerance of –3,0 K results in the requirement to profile the coldest solder joint at 236 °C, instead of 233 °C (i.e. 233 °C + 3,0 K). This tolerance is known as the “lower tolerance”. In addition to the measurement errors and variations due to mass production, the influences of the test board have to be considered. The measured temperatures of the electronic components depend also on the position on the test board because of the longitudinal and transversal temperature spread in the furnace and along the test board (see Figure 2). These temperature differences are the result of the heat flow conditions in the furnace and around the test board. Therefore, the actual temperature of a device can be up to 3,5 K higher than the measured values at the position where the device is mounted on the test board. The temperature dependence on the device position was measured independently before measuring the device temperatures on the assembled test board.

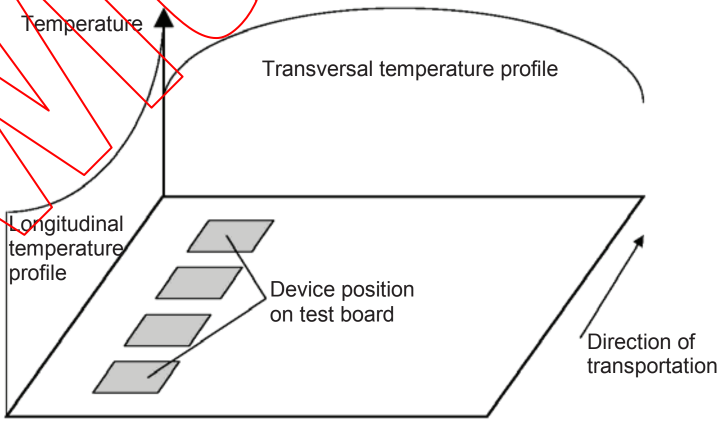

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Figure 2 – Position of the assembled devices and temperature dependence on the device position