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Edition 3.0 2022-10

TECHNICAL REPORT

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

IEC TR 60068-3-12:2022-10(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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IEC TR 60068-3-12 has been prepared by IEC technical committee 91: Electronics assembly technology. It is a Technical Report.

This third edition cancels and replaces the second edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Extended purpose

Guidance is added on how to create a reflow profile considering the tolerances resulting from the accuracy of the measuring equipment, preparation method and specifications of the component manufacturers (components, PCB, solder paste, etc.).

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b) Distinction from existing standards

The envelope profile given in this document does not represent a temperature-time profile for the qualification of materials but defines the reflow process limits for the soldering of electronic assemblies.

The schematic temperature-time-limit curves of the envelope profile are derived from generally valid findings (literature data). Additionally, tolerance considerations are given for all envelope points of the envelope profile.

In contrast to IEC TR 60068-3-12:2014, the creation of the envelope profile is not primarily linked to a concrete example.

c) Subclause 8.2 presents an approach for establishing a possible temperature profile for a lead-free reflow soldering process using SnAgCu solder paste that is taken from IEC TR 60068-3-12:2014.

d) Synergies with existing standards

Limit values and tolerances from standards and guidelines for the qualification of materials are included in this document and are listed as examples in the references.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
91/1776/DTR	91/1804/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

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

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

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INTRODUCTION

The enormous variety of materials and components processed in SMT requires to consider their thermal properties, especially in reflow soldering.

Since the second edition essentially limited its focus to lead-free soldering, there is a need to extend the contents in order to cover state of the art reflow soldering processes in general.

Reflow soldering is a joining process using an additional metal (solder) with a liquidus temperature of 450 °C or less, in which solder paste or preforms are reflowed (see ISO 857-2:2005).

Reflow soldering can be carried out with the technical processes of convection (air or nitrogen), condensation (vapour phase), radiation (e.g. infrared) or contact heat as well as with the help of low pressure (vacuum).

The goal of a qualified reflow soldering process is to create high quality and reliable solder joints at product level. It is important to avoid soldering defects and damage to components and printed circuit board.

In addition to the requirements for the formation of reliable solder joints, the specifications of the connection partners and the production requirements (temperatures, final layers, alloys, etc.), an adequate process control is an important factor. Primarily the resistance of the components and circuit boards to solder heat, as well as the specifications of the solder paste and/or flux, need to be considered. The sum of these physical limits is a theoretical temperature-time curve for a specific product (see DVS 2613).

This document is intended for engineers (e.g. development, manufacturing technology, work preparation) and operators (production) responsible for the creation and release of temperature-time (T-t) profiles for reflow soldering in surface mount technology.

This document initially was prepared by the German DKE GUK 682.2 "Thermal joining technology in electronics".

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1 Scope

This part of IEC 60068, which is a Technical Report, describes the creation of temperature-time profiles (in specific envelope profiles) for reflow soldering of electronic assemblies, considering tolerances resulting from the accuracy of the measuring equipment, preparation method and specifications of the manufacturers of components, circuit boards, solder paste, etc.).

The envelope profile given in this document does not represent a temperature-time profile for qualification but defines the reflow process window for the soldering of electronic assemblies. Qualification profiles can be found, for example, in IEC 60068-2-58 for resistance to soldering heat, or in IEC 60749-20, IEC 61760-4 and IPC/JEDEC J-STD-020E for moisture sensitivity classification of components.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Determination of an envelope reflow profile

4.1 Temperature-time-envelope curve

According to IEC 61191-1:2018, 8.2.2, manufacturers of electronic assemblies need to determine the parameters of a soldering process as follows:

> *"The process shall include, as a minimum, a reproducible time/temperature envelope including the drying/degassing operation (when required), preheating operation (when required), solder reflow operation, and a cooling operation."*

The necessary envelope points for the creation of a temperature-time-envelope curve result from the respective minima and maxima of the data for the solder heat resistance of the components and PCBs, their minimum solderability temperatures, as well as from the specifications of the solder paste and/or flux. The cycle time (time per electronic assembly) and the process time (T_0 to T_3 end) influence each other.

The temperature-time curve is described by the units in Table 1.

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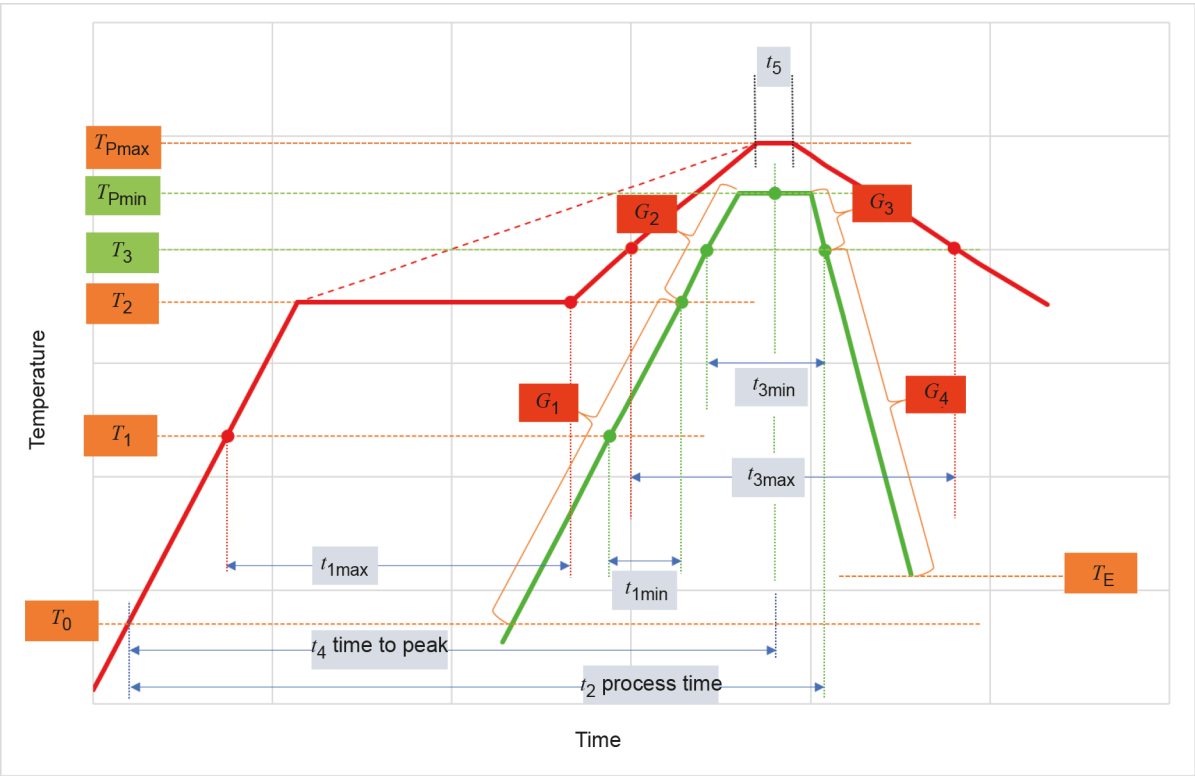
Table 1 – Temperature-time curve – Units

Physical quantity	Symbol	Units	Remark
Temperature	T	°C or K	ΔT, Temperature differences in kelvin (K) 1 K = 1 °C 0 °C = 273,15 K
Time	t	s or min	
Gradient	G	K/s	$\Delta T/\Delta t$

4.2 Diagram of a theoretical envelope reflow profile

Figure 1 shows the maximum (upper line in red) and minimum (bottom line in green) theoretical temperature-time curves for a reflow soldering process with all envelope points defining these two curves. The reflow soldering profile measured in each case is expected to be located within the boundaries of the envelope profile, as shown in Figure 1.



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NOTE The calculation of gradients is described in 5.3.

Figure 1 – Schematic envelope reflow profile

4.3 Key parameters of the envelope reflow profile

Table 1 describes the main requirements for setting the envelope points for defining the upper and lower limits of an envelope reflow profile.

The envelope points take into account material-specific data, in particular the resistance to soldering heat, as well as findings for the reliable formation of the solder joints (alloy properties, microstructure formation, etc.). Therefore, there are, for example, temperature-time curves which are measured on the components (soldering heat resistance) and temperature-time curves which are measured on or in the solder joint (soldering). In addition, the manufacturing expectations regarding the cycle time of the individual product need to be taken into account.

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The "Tolerance" column in Table 2 needs to be completed by the manufacturer of the electronic assemblies. The measurement errors are treated as "inset" limits, which means that the estimated measurement error (e.g. 5 K for the temperature measurement chain) is subtracted from the upper limit values, and added to the lower limit values. This is to ensure that the limit values cannot be exceeded.

In the "Comment" column in Table 2, corresponding notes are given for each parameter.

Table 2 – Envelope points of a reflow temperature-time-profile

Envelope point	Explanation	Typical value	Tolerance	Comment
***T*, temperature (y-axis)**				
T_0	Start temperature	T_0 > room temperature Typical: 50 °C		Reference temperature to determine the reflow profile. Temperature is significantly above room temperature – consider the production needs. Temperature at which the recording begins.
T_1	Lower preheating temperature		+5 K	Consider solder paste recommendations and needs of PCB-Assembly. IEC 61760-1:2020, 6.2.2 IPC/JEDEC J-STD-020E: T_{smin} (s = soak)
T_2	Upper preheating temperature		−5 K	Consider solder paste recommendations and needs of PCB-Assembly. IEC 61760-1:2020, 6.2.2 IPC/JEDEC J-STD-020E: T_{smax} (s = soak)
T_3	Liquidus temperature			Note the difference between solidus and liquidus temperature. The solder alloy is completely fluid (liquidus temperature). Consider solder paste recommendations. IEC 61760-1:2020, 6.2.2 IPC/JEDEC J-STD-020E): T_L (T_L = liquidus temperature
T_{Pmax}	Maximum peak temperature	T_P is below the classification temperature T_C (i.e. the max. soldering temperature T_4 of the component) $T_{pmax} = T_C - 5$ K		The maximum peak temperature is either the maximum allowed temperature at the termination (e.g. dissolution of metallization) or the maximum temperature measured on the package top side (e.g. moisture/reflow sensitivity of non-hermetic components). IEC 61760-1:2020, 6.2.2: T_4 IEC 60068-2-58:2015, 7.6.4.4: T_4 IPC/JEDEC J-STD-020E: T_P Consider: $T_P = T_C - 5$K, T_C: classification temperature IPC TM 650 2.6.27A
T_{pmin}	Minimum peak temperature	T_3 + 15 K		The minimum peak temperature is normally the temperature at the termination of the component (solder joint). Reaching the minimum peak temperature enables the solderability. IEC 60068-2-58:2015, 6.6.5 IPC-7093, IPC-7095, IPC/JEDEC J-STD-020E $T_{pmin} = (T_3 + 15$ K)

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Envelope point	Explanation	Typical value	Tolerance	Comment
T_E	End temperature			Reference temperature to determine the end of the reflow profile. Temperature is significantly below the solidus temperature. Consider the production needs. Temperature at which the calculation ends.
***t*, time (x-axis)**				
t_{1min}	Min. preheating time			Minimum time between T_1 and T_2 Consider that t_1 is part of the time to peak. Consider solder paste and component recommendations. IEC 61760-1:2020, 6.2.2
t_{1max}	Max. preheating time			Maximum time between T_1 and T_2 Consider that t_1 is part of the time to peak. Consider solder paste and component recommendations. IEC 61760-1:2020, 6.2.2
t_2	Process time from T_0 to T_3 (end of peak)			
t_{3min}	Min. time above liquidus temperature	Typical: ≥ 30 s		Time above T_3 Consider the solder alloy recommendations. t_2 in IEC 61760-1 and IEC 60068-2-58 t_L in IPC/JEDEC J-STD-020E Additional reference: DVS 2613
t_{3max}	Max. time above liquidus temperature	Typical: ≤ 90 s		Time above T_3 Consider the component recommendation. Additional reference: DVS 2613
t_4	Time to peak Process time from T_0 to T_P			Time between T_0 and T_P Consider the solder paste recommendation and component specification. t_4 in IEC 61760-1 and IEC 60068-2-58
t_5	Time on peak	Corresponding to the component specification (T_C)		Consider the component specification. The heat resistance of components limits t_5 . IPC/JEDEC J-STD-020E, Time (t_p)* within 5 K of the specified classification temperature (T_C) t_3 in IEC 61760-1 and IEC 60068-2-58
***G*, gradient $\Delta T/\Delta t$**				Ramp rate See the instructions of the component and material suppliers.
G_1	Max. heating gradient to T_2, preheating		−0,5 K/s	Consider the solder paste and component recommendation IEC 61760-1:2020, 6.2.2
G_2	Max. heating gradient from T_2 to T_4		−0,5 K/s	Consider the component recommendation IEC 61760-1:2020, 6.2.2, IPC/JEDEC J-STD-020E Max ramp-up rate (3 K/s)

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