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Thermal Cycling Test Method for Fatigue Life Characterization of Surface Mount Attachments

Developed by the SMT Attachment Reliability Test Methods Task Group (6-10d) of the Product Reliability Committee (6-10) of IPC

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Users of this publication are encouraged to participate in the development of future revisions.

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1.0 SCOPE

This specification establishes a thermal cycling test method to characterize the fatigue lifetimes of surface mount solder attachments of electronic assemblies. The surface mount devices may be solder-attached to rigid, flexible or rigid-flex printed boards. The characterization results can be used to predict field lifetime of solder attachments for the use environments and conditions of electronic assemblies.

1.1 Purpose The purpose of this document is to provide a standardized thermal cycling characterization method and reporting procedure of surface mount solder attachment for use in the study of processes and parameters, and for analytical prediction of solder joint reliability.

1.2 Definition of Terms The definition of all terms used herein **shall** be as specified in IPC-T-50, except as otherwise specified in Section 3.

1.3 Interpretation of "Shall" The imperative form of the verb, is used throughout this specification whenever a requirement is intended to express a provision that is mandatory. Deviation from a ''**shall**'' requirement may be considered if sufficient data is supplied to justify the exception.

The words ''should'' and ''may'' are used whenever it is necessary to express non-mandatory provisions. ''Will'' is used to express a declaration of purpose.

To assist the reader, the word ''**shall**'' is presented in bold characters.

1.4 Revision Level Changes The document scope was narrowed for improved alignment with actual industry usage of the standard, focusing on board-level solder attach thermal cycle characterization. Qualification is outside the scope of this document. This resulted in deletion of various comments, sections, and tables not strictly applicable to the refined scope. Wording was revised for improved clarity, accuracy, consistency, and comprehension. While not the focus, other failure modes and mechanisms may be found using this test method.

2.0 APPLICABLE DOCUMENTS

The following documents are applicable and constitute a part of this specification to the extent specified herein. Subsequent issues of, or amendments to, these documents will become a part of this specification.

2.1 IPC[1] and JEDEC[2]

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-D-279 Design Guidelines for Reliable Surface Mount Technology Printed Board Assemblies

IPC-A-600 Acceptability of Printed Boards

IPC-2221 Generic Standard on Printed Board Design

IPC-6012 Qualification and Performance Specification for Rigid Printed Boards

IPC/JEDEC J-STD-033 Packaging and Handling of Moisture Sensitive Non-Hermetic Solid State Surface Mount Device

IPC-1602 Standard for Printed Board Handling and Storage

IPC-TM-650 Test Methods Manual

IPC 9241 Guidelines for Microsection Preparation

3.0 TERMS, DEFINITIONS AND CONCEPTS

3.1 General To ensure the reliability of the solder attachment of surface mounted electronic components to a printed board, Design for Reliability (DfR) procedures (see IPC-D-279), and verification by reliability stress-testing are recommended.

During use, surface mount solder attachments can be subjected to a variety of loading conditions which can lead to premature failure. The underlying assumption is that the solder joints have been properly wetted, forming a good metallurgical bond between the solder and the base metal of the component and printed board (PB). This assures that early failures are not infant-mortalities due to defective solder joints.

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[1] www.ipc.org

[2] www.jedec.org

Because of the time-dependent creep and stress relaxation characteristics of solder, the fatigue damage and fatigue life in accelerated testing are not generally equivalent to those in operational use, but product reliability estimates can be obtained from accelerated test results through the use of appropriate acceleration factors.

The reliability of a surface mount device mounted on a circuit board is a function of solder attachment integrity and device/board interactions. Thermomechanical loading of the package, imposed by the PB through the soldered interconnects, may cause failures in other areas of the package.

3.2 Reliability Concepts In the context of this document, it is important to have a working definition of reliability, as well as good understanding of physics-of-failure and statistical failure distribution.

3.2.1 Reliability Definition The ability of a product (surface mount solder attachments) to function under given conditions and for a specified period of time at acceptable failure levels.

3.3 Physics-of-Failure

3.3.1 Creep The time-dependent visco-plastic deformation as a function of applied stress and temperature.

3.3.2 Stress Relaxation The time-dependent visco-plastic deformation decreasing the stress by converting elastic strains into plastic strains for solder.

3.3.3 Solder Creep-Fatigue Models Analytical models based on empirical data that estimate the life of solder joints subjected to cyclic creep-fatigue. The predictive lifetime is dependent on use conditions. Solder joint reliability life predictions and acceleration factor models have been reviewed in several publications [3].

3.3.4 Differential Thermal Expansion The difference in thermal expansion and contractions between materials which occurs as a result of temperature changes encountered during operational use or testing for reliability. Thermal expansions or contractions are defined by the materials' coefficient of thermal expansion (CTE). Two (2) forms of differential thermal expansion are recognized:

1) The ''global'' thermal expansion mismatch, which is the thermal expansion mismatch between components and printed boards.
2) The ''local'' thermal expansion mismatch, which is the thermal expansion mismatch between the solder itself and the materials to which it is bonded.

3.4 Test Parameters

3.4.1 Working Zone The volume in the chamber in which the temperature of the load is controlled within the specified conditions.

3.4.2 Cyclic Temperature Range/Swing The difference between maximum and minimum temperatures incurred during operational use or temperature cycling tests. See Figure 3-1 and Table 4-1.

3.4.3 Sample Temperature, Ts The temperature of the samples during temperature cycling, as measured by thermocouples, or equivalent temperature measurement apparatus, affixed to, or imbedded in, their bodies. The thermocouple or equivalent temperature measurement apparatus used in the attachment method should ensure that the entire mass of the sample(s) is reaching the temperature extremes and the dwell/soak requirements.

3.4.4 Maximum Sample Temperature, Ts(max) The maximum measured temperature experienced by the sample(s).

3.4.5 Maximum Nominal Temperature, T(max) The maximum nominal temperature for a specific test condition is the required temperature T(max) of the sample.

3.4.6 Minimum Sample Temperature, Ts(min) The minimum measured temperature experienced by the sample(s).

3.4.7 Minimum Nominal Temperature, T(min) The minimum nominal temperature for a specific test condition is the required temperature Ts(min) of the sample.

3.4.8 Mean Cyclic Temperature, T_{SJ} The mean of the maximum nominal temperature and the minimum nominal temperature.

3.4.9 Nominal ΔT The difference between nominal T(max) and nominal T(min) for a specific test condition.

3.4.10 Dwell/Soak Time, t_D The total time the sample temperature is within a specified range of each nominal T(max) and T(min) (see Table 4-1). The dwell time is of particular importance for accelerated tests, since during accelerated testing the creep process is substantially incomplete. The dwell allows for a correction of the effect of the incomplete creep process relative to the product use temperature cycles which are typically long enough to allow the creep process to be complete at every cycle dwell.