JEDEC STANDARD

Temperature Cycling

JESD22-A104C

(Revision of JESD22-A104-B)

MAY 2005

JEDEC SOLID STATE TECHNOLOGY ASSOCIATION

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TEST METHOD A104C
TEMPERATURE CYCLING

(From Board Ballot JCB-00-16, and JCB-05-82, formulated under the cognizance of the JC-14.1 Committee on Reliability Test methods for Packaged Devices.)

1 Scope

This specification applies to single, dual and triple chamber temperature cycling and covers component and solder interconnection testing. In single chamber cycling, the load is placed in a stationary chamber, and is heated or cooled by introducing hot or cold air into the chamber. In dual chamber cycling, the load is placed on a moving platform that shuttles between stationary chambers maintained at fixed temperatures. In triple chamber temperature cycling there are three chambers and the load is moved between them.

This test is conducted to determine the ability of components and solder interconnects to withstand mechanical stresses induced by alternating high and low temperature extremes. Permanent changes in electrical and/or physical characteristics can result from these mechanical stresses.

2 Terms and definitions

2.1 Load

The sample(s) and associated fixtures (trays, racks, etc.) in the chamber during the test.

2.2 Working zone

The volume in the chamber(s) in which the temperature of the load is controlled within the specified conditions.

2.3 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, attachment method used should ensure that the entire mass of the sample(s) is reaching the temperature extremes and the soak requirements.

2 Terms and definitions (cont'd)

2.4 Maximum sample temperature: Ts(max)

The maximum temperature experienced by the sample(s) as measured by thermocouples, per 2.3.

2.5 Minimum sample temperature: Ts(min)

The minimum temperature experienced by the sample(s) as measured by thermocouples, per 2.3.

2.6 Load transfer time

The time it takes to physically transfer the load from one temperature chamber and introduce it into the other. Load transfer applies to dual and triple chamber cycling.

2.7 Maximum load

The largest load that can be placed in the chamber and still meet the specified temperature cycling requirements as verified by thermocouples, per 2.3.

2.8 Nominal ΔT

The difference between nominal Ts(max) and nominal Ts(min) for the Temperature Cycling Test Condition; see Table 1.

2.9 Soak time

The total time the sample temperature is within a specified range of each nominal Ts(max) and nominal Ts(min). This range is defined as the time Ts is at –5 °C to +10/+15 °C (dependent on the Test Condition tolerance) of Ts(max)nominal for the upper end of the cycle and the time Ts is +5 °C to –10 °C of Ts(min) nominal for the lower end of the cycle.

2.10 Soak temperature

The temperature range that is –5 °C to +10/+15 °C (dependent on the Test Condition tolerance) of Ts(max)nominal and +5 °C to –10 °C of Ts(min) nominal.

2.11 Cycle time

Time between one high temperature extreme to the next, or from one low temperature extreme to the next, for a given sample; see Figure 1.

2 Terms and definitions (cont'd)

2.12 Ramp rate

The rate of temperature increase or decrease per unit of time for the sample(s). Ramp rate should be measured for the linear portion of the profile curve, which is generally the range between 10% and 90% of the Test Condition temperature range; see points a and b in Figure 1. Note: Ramp rate can be load dependent and should be verified for the load being tested.

2.13 Test conditions

Test Conditions are the various temperature cycle range options listed in Table 1.

2.14 Soak mode

Each Test Condition will have four possible Soak Modes. These Soak Modes are listed in Table 2. The soak mode selected is dependent on the failure mechanism of interest.

2.15 Nominal Ts(max)

Nominal Ts (max) is the temperature of the sample required to meet the maximum nominal temperature for a specific test condition; see Table 1.

2.16 Nominal Ts(min)

Nominal Ts(min) is the temperature of the sample required to meet the minimum nominal temperature for a specific test condition; see Table 1.

3 Apparatus

The chamber(s) used shall be capable of providing and controlling the specified temperatures and cycle timing in the working zone(s), when the chamber is loaded with a maximum load. Direct heat conduction to sample(s) shall be minimized. The capability of each chamber achieving the sample temperature requirements shall be verified across each chamber by one or both of the following methods:

a) Periodic calibration using instrumented parts and a maximum load, and continual monitoring during each test of such fixed tool thermocouple temperature measurement(s) as adequate to ensure run-to-run repeatability.

b) Continual monitoring during each test of an instrumented part or parts placed at worst-case temperature locations (for example, this may be the corners and middle of the load).

4 Procedure

Sample(s) shall be placed in such a position with respect to the air stream such that there is substantially no obstruction to the flow of air across and around each sample(s). When special mounting is required, it shall be specified. The sample shall then be subjected to the specified temperature cycling test condition for the specified number of cycles (e.g., JESD 47 for qualification or as agreed to between the supplier and user). Completion of the total number of cycles specified for the test may be interrupted for interim end-point testing, test chamber loading or unloading of device lots, electrical test of samples at specified intervals or as the result of power or equipment failure. However, if the aggregate number of times of all interruptions exceeds 10% of the total number of cycles specified, the test must be restarted from the beginning. If the thermocouple is affixed to the sample body, the amount of glue or tape used shall be minimized to insure proper temperature measurements. The thermocouple, or equivalent temperature measurement apparatus, attachment method used should ensure that the entire mass of the sample(s) is reaching the temperature extremes and the soak requirements.

4.1 Nominal cycle rates

Nominal cycle rates are dependent on the Soak Mode selected.

4.1.1 Component cycle rates

Typical component level temperature cycle rates are in the range of 1 to 3 cycles per hour (cph). Typical failure mechanisms include, but are not limited to, fatigue (such as metal circuit fatigue) and delamination. For certain failure mechanisms, such as ball bond integrity, faster rates, >3 cph can be used, if the temperature cycling chambers are capable of meeting the Ts nominal and soak requirements for the given Test Condition.

4.1.2 Solder interconnect cycle rates

Typical solder interconnect cycle rates are slower, in the range of 1 to 2 cph, when solder joint fatigue evaluations are performed. These include flip chip, ball grid array and stacked packages with solder interconnections. Cycle frequency and soak time is more significant for solder interconnections.

4.1.3 Tin whisker cycle rate

Tin whisker cycle rate shall be about 3 cycles per hour as stated in JESD22A121.

4.2 Maximum and minimum temperature

The maximum and minimum sample temperatures measured shall be within the range stated in Table 1 for the specific test condition being used and the nominal ΔT shall be at least attained.

4 Procedure (cont'd)

Table 1 — Temperature cycling test conditions

Test Condition*	Nominal Ts(min)(°C) with Tolerances	Nominal Ts(max)(°C) with Tolerances
A	-55(+0, -10)	+85(+10, -0)
B	-55(+0, -10)	+125(+15, -0)
C	-65(+0, -10)	+150(+15, -0)
G	-40(+0, -10)	+125(+15, -0)
H	-55(+0, -10)	+150(+15, -0)
I	-40(+0, -10)	+115(+15, -0)
J	-0(+0, -10)	+100(+15, -0)
K	-0(+0, -10)	+125(+15, -0)
L	-55(+0, -10)	+110(+15, -0)
M	-40(+0, -10)	+150(+15, -0)
N	-40(+0, -10)	+85(+10, -0)

***CAUTION**: Care should be taken when selecting Test Conditions, since: 1) the Ts(max) requirement for a specific Test Condition may exceed the glass transition temperature of some package materials which may induce failure mechanisms not normally seen during design application conditions in the field, and 2) CTE differences over the test condition temperature range can produce premature failure of plated through holes in the test board, thus limiting electrical readout capability for the parts on test. Test Conditions that exceed 125 °C for Ts(max) are not recommended to Pb/Sn solder compositions.

NOTE Temperature cycling test conditions different from Table 1 can be used. However, test conditions should meet the soak, cycles per hour and ramp rate recommendations for the failure mechanism being tested. These conditions must be documented as indicated in Section 7(f).

Table 2 — Soak mode conditions

Soak Mode	Minimum Soak Time at Soak Temperature(max) & Soak Temperature(min) (minutes)
1	1
2	5
3	10
4	15

NOTE Soak Modes different from Table 2 can be used, however, test conditions should be appropriate for the failure mechanism being tested. These conditions must be documented as indicated in Section 7(f).

4.3 Upper and lower soak times

Upper and Lower Soak Times vary by the Soak Mode selected; see Table 2. During this soak time the specimen shall reach the required nominal temperature, either Ts(max) or Ts(min).

4.4 Upper and lower soak temperatures

Upper and Lower Soak Temperatures vary with the Test Condition selected; see Table 1.

4.5 Soak modes

Soak Modes are listed in Table 2**.** Soak Modes with longer soak times than those shown in Table 2 are not compatible with standard cycle rates and should be selected only as required for a specific failure mechanism.

4.5.1 Component soak mode

In component temperature cycling, Soak Mode 1 is typically used.

4.5.2 Interconnect soak mode

Soak Modes 2, 3 and 4 are generally used for solder fatigue and creep testing associated with interconnections such as flip chip or BGA solder joints.

4.5.3 Tin whisker soak mode

Tin whisker soak mode shall be 5 to 10 minutes as stated in JESD22A121. This equates to soak mode 2, see Table 2.

4.6 Nominal cycle time

Nominal cycle times vary with the Soak Mode selected. Table 3 lists typical cycle rates for components versus test condition and soak mode. For solder interconnections, cycle times less than 30 minutes are not recommended.

Table 3 — Typical frequency and soak mode for test conditions

Condition	Typical Cycles/Hr	Typical Soak Mode
A	2 – 3	1, 2 & 3
B	2 – 3	1 & 2
C	2	1 & 2
G	< 1 – 2	1, 2, 3 & 4
H	2	1 & 2
I	1 – 2	1, 2, 3 & 4
J	1 – 3	1, 2, 3 & 4
K	1 – 3	1, 2, 3 & 4
L	1 – 3	1, 2, 3 & 4
M	1 – 3	1, 2, 3 & 4
N	1 – 3	1, 2, & 3

4.7 Ramp rate

4.7.1 Component ramp rate

Ramp rate is not critical for most component testing.

4.7.2 Interconnect ramp rate

When testing interconnections for solder joint fatigue, it is important to avoid transient thermal gradients in the samples on test. Samples with large thermal mass and low heat transfer efficiency require ramp rates slow enough to compensate for the thermal mass. The temperature of the sample should be within a few degrees of the ambient temperature during the temperature ramps. Typical ramp rate for this situation is 15 °C/minute or less for any portion of the cycle, with a preferred rate of 10 °C to 14 °C/minute. For samples of large thermal mass, use of a single zone chamber may be required to achieve the best ramp rate. For samples without a thermal mass constraint, the ramp rate can be faster and dual chambers can be used.

Typical test requirements for solder interconnection are listed in Table 4. The combination of ramp rate and soak time are important when testing solder interconnections.

Table 4 — Recommended test conditions for solder interconnection temperature cycling

Test Condition***	Soak Mode	Ramp Rate (°C/minute)	Cycle Rate (cph)
G,I,J,K,L	2	Thermal Mass Dependent	2
G,I,J,K,L	3	Thermal Mass Dependent	≤2
G,I,J,K,L	4	Thermal Mass Dependent	<1

*** **CAUTION**: Care should be taken in selection of Test Conditions since the Ts(min) may cause cracking of the Printed Wiring Board plated through holes and/or wiring, thus inhibiting electrical readouts associated with the solder interconnections being tested.

4.8 Load transfer time (**Dual chamber only**)

Load transfer time shall be less than 1 minute, in order to maintain a uniform temperature profile across the load.

4.9 Measurements

Visual examination and electrical measurements, which consists of parametric and functional test, shall be performed as specified in the applicable procurement document or data sheet. Electrical test may be performed either in-situ or at an ambient or extreme temperature. Failure resistance criteria must be adjusted based on the temperature of the sample at time of test. In addition, hermeticity test(s) per Test Method A109 shall also be performed for hermetic devices.

5 Failure criteria

Failure criteria shall include, but not be limited to, hermeticity for hermetic devices, parametric limits, functional limits, mechanical damage and warpage. Parametric and functional limits shall be defined by the applicable procurement document. Mechanical damage shall not include damage induced by fixturing or handling or the damage is not critical to the package performance in the specific application.

6 Summary

The following details shall be specified in the applicable procurement documents:

a) Special mounting, if applicable; see 3.

b) Temperature extremes; see Table 1, soak time; see Table 2, sample cooling and heating ramp rate and number of cycles, or specific component requirements.

c) Interim measurement intervals, when required.

d) Special acceptance criteria for examinations, seal tests (for hermetic packages), internal bond integrity tests and electrical tests if other than those specified in the device specification.

e) For qualification testing, sample size and quality level.

f) Temperature extremes other than in Table 1. Specify the number of cycles, temperature extremes, soak time, cycles per hour, tolerance on temperature extremes (if different from Table 1), ramp rate and interim measurements, if required.

Annex A

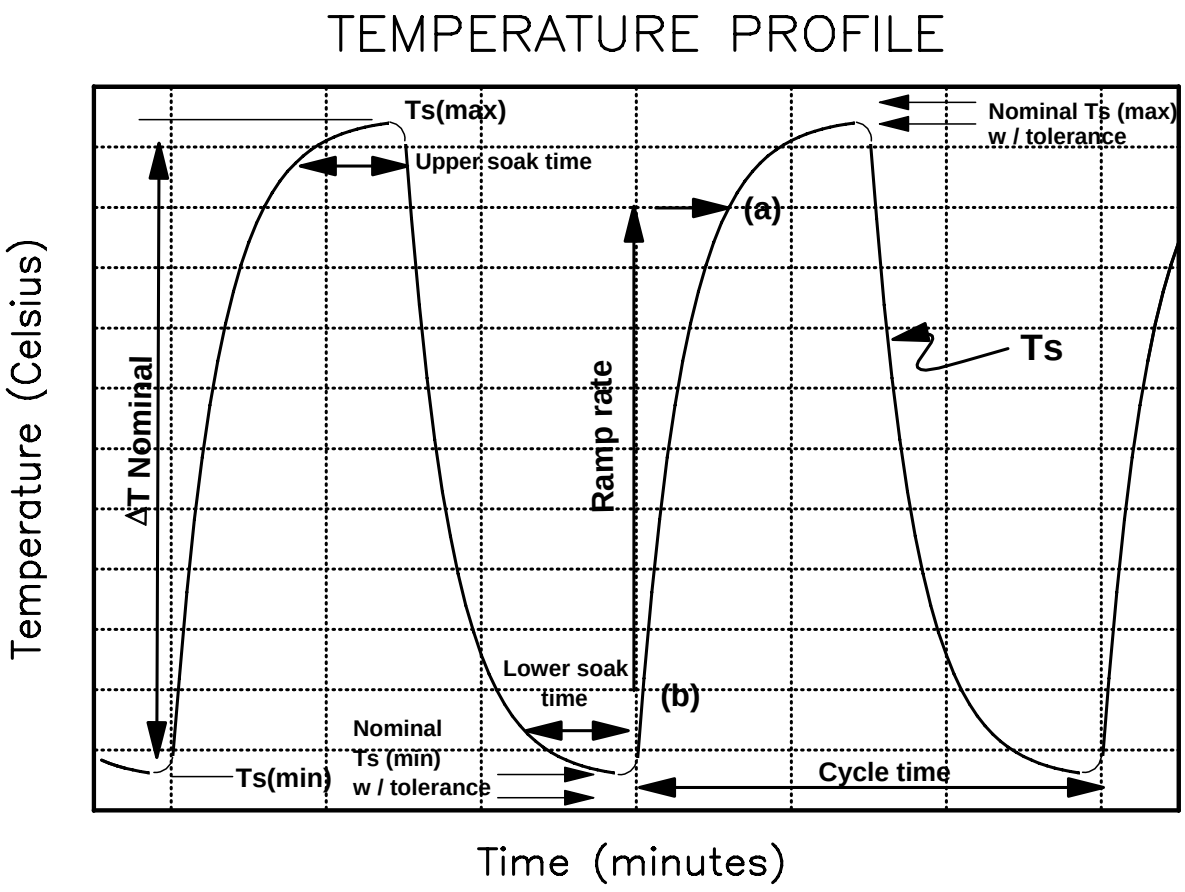

Figure 1 — Representative temperature profile for thermal cycle test conditions.

NOTE Ramp rate should be measured for the linear portion of the profile curve, which is generally the range between 10% and 90% of the Test Condition temperature range; see points a and b in Figure 1.

Annex B (informative) Differences between JESD22A104C and JESD22-A104-B

This table briefly describes most of the changes made to entries that appear in this standard, JESD22A104C, compared to its predecessor, JESD22-A104-B (July 2000). If the change to a concept involves any words added or deleted (excluding deletion of accidentally repeated words), it is included. Some punctuation changes are not included.

Page	Description
All	Renumbered document to conform with JM7, JEDEC Style Manual
4	Added new subclause 4.1.3
5	In Table 1 – added test condition ‘N’
6	Added new subclause 4.5.3
6	In Table 3 – added test condition ‘N’ and under condition ‘A’ added soak mode 3

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1. I recommend changes to the following:

☐ Requirement, clause number _____

☐ Test method number _____ Clause number _____

The referenced clause number has proven to be:

☐ Unclear ☐ Too Rigid ☐ In Error

☐ Other _____

2. Recommendations for correction:

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