Microsemi Power Modules

Reliability tests for Automotive application on basis of AEC-Q101
Introduction

With reference to standard AEC-Q101, designed by Automotive Electronics Council for Stress Qualification of Discrete Semiconductors, Microsemi has developed an evaluation program for its Power Modules intended for use in Automotive applications.

Purpose:
The purpose of this evaluation is to understand Microsemi Power Modules capability to meet as much as possible the AEC-Q101 requirements defined for Discrete Semiconductors.

Modules used for this qualification:
Tests are conducted on standard modules built with copper base-plate, regular soldering and potting material. Samples used for tests are SP3 standard products, reflecting the assembly processes used for Microsemi SP product line.

Conclusion

This document summarizes the reliability tests performed on Microsemi Power Modules and the main results. Tests which are not reported here are still in process or completed but results still under analysis.

Microsemi Power Modules are capable of meeting the majority of AEC-Q101 requirements and a baseline has been established from which to compare the results of future improvements.

- Primary limitations identified are during Temperature cycling and HAST testing. i.e. limitation to 700 temperature cycles (-40/+105°C), cosmetic cracks in packages after HAST (96hrs/130°C/85%RH).
- Power cycle capability was established per the specification, wire bonds lift up after 300K cycles (Delta Tj 100°C)

Microsemi offers improved solutions with specific material that allows to extend the Power Modules capability towards these reliability tests: i.e. usage of AlSiC or CuW base-plate, different ceramic material for substrates, specific potting material for extended temperature range (as -65°C), …

Contents of this reliability report

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Test #5 and #6  HTRB and HTGB (high temp, reverse bias, gate bias)

Purpose: This test is used to determine the effects of bias conditions and temperature on devices over time. It simulates the devices operating condition in an accelerated way, per AEC-Q101 qualification requirements.

Conditions: Per JESD22-A108

HTRB: 80% of device Breakdown Voltage, 1024 hrs at 125°C

HTGB: Vgs=24V, 1024 hrs at 125°C

Criteria: Dielectric test at room temperature, parametric tests performed at room temperature and at 125°C, before and after exposure to HTRB or HTGB stress.

No drift accepted after the HTRB or HTGB on both dielectric and parametric tests.

Results: HTRB: All submitted parts PASS the test, with no drift of electrical parameters after 1024 hrs

HTGB: All submitted parts PASS the test, with no drift of electrical parameters after 1024 hrs
Test #7  TEMPERATURE CYCLING

Purpose : 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 according to the AEC-Q101 qualification requirements.

Conditions : Per JESD22-A104
Temperature cycle : -40°C to 105°C
Dwell time : 15min.
Transfer from low to high temperature : 12°C/min.

Criteria : Dielectric test, parametric tests and ΔVDS test performed at room temperature
Performed before and after the Temperature cycling stress, with intermediate tests after every 100 cycles.
Electrical and ΔVDS results within the module datasheet

Acoustic Imaging analysis for solder joint performed before and after the Temperature cycling stress, with intermediate tests after every 100 cycles.
No delamination accepted in solder joints.

Results : No dielectric failure after 1K cycles

RDSon : a drift is observed after 600 cycles, increasing exponentially after 800 cycles. Modules are tested within the datasheet tolerances up to 800 cycles, some values starting to be out of the datasheet tolerances at 1K cycles.

ΔVDS : a drift is observed after 700 cycles, increasing exponentially with the number of temperature cycles to reach 4% average drift at 1K cycles.

Acoustic imaging confirms delamination process starting after 700 cycles and affecting the thermal behavior of the device, resulting in ΔVDS drift.
**Test #8**  AUTOCLAVE  (moisture resistance)

**Purpose:**

The “Unbiased Autoclave Test” is performed to evaluate the moisture resistance integrity of non-hermetic packaged device using moisture condensing or moisture saturated stream environments, per AEC-Q101 qualification requirements.

It is a high accelerated test which employs conditions of pressure humidity and temperature under condensing conditions to accelerate moisture penetration through the external protection material. This test is used to identify failure mechanisms internal to the package.

**Conditions:**

Per JESD22-A102
96 hrs at 121°C, 100%RH, vapor pressure of 15 psig
No bias.

**Criteria:**

Dielectric test at room temperature, parametric tests performed at room temperature and at 125°C, before and after exposure to moisture conditions.

No drift accepted after the Autoclave test on both dielectric and parametric tests.

External and internal visual inspection: no crack accepted at package level or any elements of the assembly

**Results:**

All submitted parts PASS the test, with no visual failures, no drift of electrical parameters after 96hrs at 121°C / 100%RH

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**Test #9**  H3TRB  (high humidity, high temp, reverse bias)

**Purpose:**

The Temperature humidity bias life test is performed for the purpose of evaluating the reliability of non-hermetic packaged devices in humid environments, per AEC-Q101 qualification requirements. It employs conditions of temperature, humidity and bias which accelerate the penetration of moisture through the external protective material.

**Conditions:**

Per JESD22-A101

1000 hrs at 85°C, 85%RH
100V drain-source bias

**Criteria:**

Dielectric test at room temperature, parametric tests performed at room temperature and at 125°C, before and after exposure to stress conditions.

No drift accepted after the H3TRB test on both dielectric and parametric tests.

External and internal visual inspection: no crack accepted at package level or any elements of the assembly

**Results:**

All submitted parts PASS the test, with no visual failures, no drift of electrical parameters after 1000hrs at 85°C / 85%RH
Test #9 alt HAST (highly accelerated stress test)

Purpose: The highly accelerated temperature and humidity stress test is performed for the purpose of evaluating the reliability of non-hermetic packaged devices in humid environments, per AEC-Q101 qualification requirements. It employs severe conditions of temperature, humidity and bias which accelerate the penetration of moisture through the external protective material.

Conditions: Per JESD22-A110
- 96 hrs at 130°C, 85%RH
- 42V drain-source bias

Criteria: Dielectric test at room temperature, parametric tests performed at room temperature and at 125°C, before and after exposure to stress conditions.
- No drift accepted after the HAST test on both dielectric and parametric tests.
- External and internal visual inspection: no crack accepted at package level or any elements of the assembly

Results: All submitted parts PASS the tests criteria, no drift of electrical parameters after 96hrs at 130°C/85%RH

- Some modules under test exhibit small cracks in the center of the plastic cover (2 SP3 modules revealed this failure on the 13 tested). This does not affect the electrical performance and the reliability of the module if used in the conditions defined by Microsemi specification.
Test #10  INTERMITTENT OPERATIONAL LIFE  
(Power cycling test)

Purpose: This test is intended to evaluate the reliability of the power module and the ability to withstand without failure the temperature cycle induced by starts and stops of the complete power system and/or vehicle, per AEC-Q101 qualification requirements.

Conditions: Per MIL-STD-750 Met.1037

- Delta Junction temperature: 100°C min
- Modules mounted onto water cooled heatsink, maintained at 20°C with a cooling station
- Each module is driven separately in linear mode, effective dissipated power is monitored and adjusted to meet requested Junction temperature.

Cycle duration (6 seconds on state, 6 seconds off state)

Criteria: Power cycling is run up to failure of each device under test, in order to determine meantime for first failure and average life time of the modules under test.

Failure is reported as the number of cycles met by a given module when, due to internal degradation of the module, the Vgs voltage needs to be increased to meet the requested junction temperature.
Results: Failure signature is in general wire bonds lift up.

After each device has failed in test, the Life Time is calculated on basis of the number of cycles achieved by each device before to fail.

In the conditions described above, DELTA Tj = 100°C

First failure: 261 K cycles

Operational Life Time: 300 K cycles (for 90% of operating devices)

Average time to failure (MTBF): 453 K cycles
**Test #17 and #18 VIBRATIONS and MECHANICAL SHOCKS**

**Purpose:** Vibrations tests are intended to determine the ability of the device to withstand severe vibration as a result of motion produced by transportation or field operation.

Mechanical shock test is to determine the compatibility of the device to withstand severe shocks as a result of suddenly applied forces or abrupt change in motion produced by handling, transportation or field operation.

Modules submitted to these tests are representing all the wire diameters used for wire bonding process of Microsemi Power Modules.

**Conditions:** Per JESD22-B103 (vibrations) and JESD22-B104 (shocks)

**Vibrations (Sinusoidal mode):**
- Frequency: from 10 to 1000 Hz
- Peak acceleration: 10g in the 3 orientations
- Displacement: 1mm peak to peak
- Duration: 16 minutes in each of the orientations X Y Z
- Sweep rate: 1 decade/min

**Vibrations (Random mode):**
- Condition A
- Duration: 30 minutes in each of 3 orthogonal axis

<table>
<thead>
<tr>
<th>Frequencies (Hz)</th>
<th>Power Spectral Density (PSD) level, G squared/Hz</th>
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<td>8</td>
<td>1</td>
</tr>
<tr>
<td>40</td>
<td>0.1</td>
</tr>
<tr>
<td>50</td>
<td>0.3</td>
</tr>
<tr>
<td>70</td>
<td>0.3</td>
</tr>
<tr>
<td>200</td>
<td>0.03</td>
</tr>
<tr>
<td>500</td>
<td>0.01</td>
</tr>
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</table>

**Mechanical shocks:**
- Acceleration peak: 1,500g ±50
- Shocks: 5 in each of two directions of three orthogonal axis (30 shocks in total).
- Pulse duration: 0.5ms ±0.1

**Criteria:**
- Dielectric test at room temperature, parametric tests performed at room temperature, before and after exposure to stress conditions.
- No drift accepted after the Vibrations and Mechanical Shocks, on both dielectric and parametric tests.
- External and internal visual inspection: no crack accepted at package level or any elements of the assembly

**Results:** All submitted parts PASS the test, with no visual failures, no drift of electrical parameters after Vibrations and Mechanical Shocks