Assessment of the SMT assemblies and Improvements through Accelerated testing methods

SMTA Chapter Meeting 18th Jan’2014, India
Contents

- SMT solder defects due Thermo-Mechanical stress- what and how!
- How much is the affect?
- What methods to follow to detect the defects?
- Acceleration and factors needed for testing
- Benefits to the industry
There are several factors which affect the solder joints. Factors may be environmental, mechanical etc.

**Direct Load conditions:**
- Differential thermal Expansion,
- Thermal Shock,
- Vibration (continuous like during transportation),
- Mechanical Shock

Factors may act Singly, Simultaneously or sequentially during the end use.

Solder joint functions as a high homologous temperature under Thermo Mechanical fatigue condition

Challenge for the fields like Military, Aerospace and satellites
SMT solder joint defects - what and how…?

Vibration, Thermal Shock, Mechanical Shock

- Direct possible during use
- Resistance against failures induced depends on Solder Joint Strength

Differential Thermal Expansion, CTE

- Changing temperatures due to Power Dissipation
- CTE: Load Fluctuations, ON/OFF Cycles
SMT solder joint defects - what and how…?

1. Temperature Cycle Damage
   - Creep / Stress Relaxation-enhanced fatigue of solder Joints
   - Visco-plastic Strain Causes fatigue damage which accumulate cycle to cycle
   - Solder joint is loaded by thermal expansion mismatch

2. Vibration Damage
   - Vibration causes elastic behavior of joint
   - Occurrence in Automotive, Military and aerospace applications

3. Thermal Shocks
   - Extremely rapid thermal changes (30°C/min+) results in PCBA wrapping
   - Rapid changes in the environmental conditions – sun to shade space
   - Sudden and large power changes
How much is the affect?

Studies indicates that around 48% of Electronics failures are likely due to solder joint failure.

Surface mount solder joint Reliability is merely governed by ‘infant mortality’ and ‘constant failure rate’ but established by ‘Wear out’ failure region.

Electronics Assembly more likely fails due to failure of component in short-term and solder joint failure in Long-term.
What methods to follow to detect the defects?

1. **Thermal Cycling Test (TCT)**

   **Standards:**
   - Mil-Std-883 Method 1010 / JEDEC JESD22-A104.
   - Ramp Rate $\geq 10^\circ C - 14^\circ C$/min
   - Soak Time $\geq 10$ min (mode 3)

   **Cycling Condition as below:**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Low Temp</th>
<th>High Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-55 (+0/-10) °C</td>
<td>85 (+10,-0) °C</td>
</tr>
<tr>
<td>B</td>
<td>-55 (+0/-10) °C</td>
<td>125 (+10,-0) °C</td>
</tr>
<tr>
<td>C</td>
<td>-65 (+0/-10) °C</td>
<td>150 (+10,-0) °C</td>
</tr>
<tr>
<td>D</td>
<td>-65 (+0/-10) °C</td>
<td>200 (+10,-0) °C</td>
</tr>
<tr>
<td>F</td>
<td>-65 (+0/-10) °C</td>
<td>175 (+10,-0) °C</td>
</tr>
<tr>
<td>G</td>
<td>-40 (+0/-10) °C</td>
<td>125 (+10,-0) °C</td>
</tr>
<tr>
<td>H</td>
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</tr>
</tbody>
</table>

   **Cycles $> 10$ to 1000**
What methods to follow to detect the defects?

2. Thermal shock Test (TST)

-In thermal shock, the extremely rapid temperature changes (about 30°C/minute and above)

-Results in warping of the surface mount assembly.

-When the boards are plunged into a new thermal environment. The warpages result in tensile and shear stresses

-Thus, even assemblies with matched Coefficients of thermal expansion will exhibit solder joint Failures when subjected to thermal shock.

Example of Board Warpage Due to thermal shock

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</tbody>
</table>

Cycles > 15
What methods to follow to detect the defects?

2. Vibration Test (Random)

Non-Operating Vibration test:
Freq: 1-125 Hz, ASD: 2.16 Grms, Shape of ASD Curve: Flat
Test Duration: 90 min
Axis of Vibration: X, Y and Z (with 30 min each)

Standards: IEC 60068-2-64, IEC 60068-2-47

Operating Vibration test:
Freq: 5-300 Hz, ASD: 0.5 Grms, Shape of ASD Curve: Flat
Test Duration: 90 min
Axis of Vibration: X, Y and Z (with 30 min each)

Standards: IEC 60068-2-64, IEC 60068-2-47

Board Level Drop test
Can be conducted along with Vibration Tests
What methods to follow to detect the defects?

HALT / HASS / HASA:-

HALT - Highly Accelerated Life Test: Design test used to improve the robustness/reliability of a product through TEST-FAIL-FIX process where applied stresses are beyond the specified operating limits.

HASS – Highly Accelerated Stress Screening: Used to improve the robustness/reliability of a product through test-fail-fix process where the applied stresses are beyond the specified operating limits. This is applied to 100% of the manufactured units.

HASA - Highly Accelerated Stress Audit: performed via sample testing as opposed to 100% that is done with HASS.

Examples of HALT on PCB assembly

Example of HALT
Accelerated Tests and factors needed for testing

- Tests use for demonstrating the solder joint reliability with can be accelerated
- Sample size to be decided by Test lab/engineer – preferably 20 + samples
- Factors like Temp, Humidity to be selected singly or simultaneously or sequentially
- Use the appropriate law /rule for calculating Acceleration factor like Coffin-Manson rule, Arrhenius Equation, inverse power Law etc
- Allow product to age than squeezing timelines for cost saving purpose

**Example of Accelerated Temp/Humidity Test**

<table>
<thead>
<tr>
<th>Total test time</th>
<th>47 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration (Temp.)</td>
<td>50°C</td>
</tr>
</tbody>
</table>

| Activation Energy | 0.7 eV/molec |
| Boltzman Constant | 8.6174E-05 eV/K |
| Room Temperature | 25°C |
| Acceleration Temperature | 50°C |
| Acceleration Factor | 8.24488727 |
Summary Of the Tests

- Thermal Cycling Test
- Thermal Shock Test
- Mechanical Vibration Test
- HALT
- Accelerated Tests
Design for Solder Attachment Reliability

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component size</td>
<td></td>
</tr>
<tr>
<td>Attachment Type</td>
<td>Leaded component better than leadless</td>
</tr>
<tr>
<td>Solder Joint Area</td>
<td></td>
</tr>
<tr>
<td>Solder Joint Fillet</td>
<td></td>
</tr>
<tr>
<td>Lead Stiffness</td>
<td></td>
</tr>
<tr>
<td>CTE mismatch</td>
<td></td>
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</tbody>
</table>
Benefits to the Industry

- Mature product will be attained very early
- Production Release will be expedited
- Warranty costs will be greatly reduced
- Customer satisfaction will be greatly enhanced
Questions..?
Thank you..!!

-Pankaj Bansod
bpankaj358@gmail.com