PWB Thermal Management and UL Pre-Selection Programs

Presented by
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Underwriters Laboratories Inc (UL) is an independent, not-for-profit safety testing and certification organization. Founded in 1894, UL has earned a reputation as a global leader in product safety standards development, testing and certification.
Background on UL’s Certification Program for PWBs and Laminates
Printed Board Terminology

Many terms are used for circuit boards in the electronics industry
• Printed Boards (PBs)
• Printed Circuit Boards (PCBs)
• Printed Wiring Boards (PWBs)

Official IPC term is currently “Printed Boards”

In order to reduce confusion with other components and end products tested within UL, we continue to use the term PWBs which will be used throughout this presentation for PBs.
Demand Driver – for UL Certification

End Product Safety Issues for PWB

- Intended location
- Environmental issues – RoHS requirements
- Maximum operating temperature
- Flammability
- Material characteristics
- Conductor Adhesion
- Delamination
Pre-selection

The process of assessing and choosing insulating materials for electrical products.
Advantages of Pre-selection

- Aides in material selection during the design stage
- Compare and evaluate material performance levels
- Eliminate testing each material in specific part configurations
- Faster qualification of alternate materials
- Pre-selection successfully used as a material performance specification in product standards for decades
- Faster time to market
PWB Property Characterization

PWB Parameters

- Solder Limits
- Maximum Operating Temperature (MOT)
  - Conductor Adhesion (Bond Strength)
  - Delamination
- Flammability Classification
- Direct Support (DSR)
- Comparative Tracking Index (CTI)
PWB Solder Limits

Solder limits represent assembly process
• Maximum surface temperature
• Cumulative exposure time

Simulated on PWB samples with thermal shock (thermal stress) test.
• Designed to evaluate the physical fatigue of boards exposed to the anticipated assembly soldering temperatures (Solder Limits)

Test with maximum temperature or multiple solder limit
• Specified by PWB mfr
Multiple Solder Limits

Assembly processes now use Surface Mount Technology (SMT)

- Traditional solder float test does not represent industry practices
- PWBs exposed to at least 3 cycles of reflow process
  - #1 cycle for single sided, #2 cycles for double sided, #3 cycle for rework
- Multiple solder limits are used to represent the temperature profile during the soldering operation
Maximum Operating Temperature (MOT)

MOT represents PWB maximum continuous use temperature
- End product exposure under normal operating conditions
- Minimum acceptable MOT specified by end product requirements
- Can not exceed dielectric material mechanical or electrical RTI

Simulated on PWBs with short term thermal conditioning
- Exposure temperature based on PWB mfr request
- MOT determined by analysis of PWB physical properties
  - Conductor adhesion and board delamination
Relative Thermal Index (RTI)

A temperature assigned to the dielectric material
- Does not unacceptably degrade the material
- Electrical and Mechanical properties
  - Electrical – Dielectric Strength
  - Mechanical – Flexural Strength and Tensile Strength

Determined by a benchmark comparison of temperature, time, and critical property degradation after long-term thermal aging
PWB Flammability Classification

Classification represents small scale sample evaluation and burn time

- Flame Ratings - V-0, V-1, HB, VTM-0, VTM-1, VTM-2

Determined by performing UL94 burning tests on the board

- With and without coatings based on finished board
- After thermal shock (thermal stress) exposure

Minimum acceptable flame class is specified by end product requirements
Direct Support Requirements (DSR) represent performance characteristics for Recognized laminates in direct contact with current carrying parts at 120V or less.
DSR Performance Tests

Comparative Tracking Index (CTI)
  • determine spacing requirements with addition of wet contaminant;

Dielectric Strength (DS)
  • establish insulation resistance baseline at 5000V or 6.89 kV/mm;

High Current Arc Ignition (HAI)
  • simulate loose connections and broken leads;

Hot Wire Ignition (HWI)
  • determine ignition properties when adjacent to or supporting an insulated or uninsulated wire;

Volume Resistivity (VR)
  • determine if material is an insulator or a semi-conductive material;

Heat deflection
  • identify and restrict the use of low temperature polymeric materials
  • not required for thermoset or film materials
How lead-free affects thermal management of the PWB
Global Electronics Movement

Boards required to be
• Smaller
• Cheaper
• Lead-free

OEMs turning to
• Unique Rigid PWB constructions
• Flexible PWBs
Communication is Key

Communication needed up/down the supply chain

Switching to lead-free involves the OEM, EMS, Assembler and PWB Fabricator,
• determine if lead-free is appropriate direction for end product
RoHS Directive

Restricted Substances

- Cadmium
- Hexavalent Chromium
- Lead
- Mercury
- Brominated Flame Retardants
  - Polybrominated Biphenyl (PBB)
  - Polybrominated Diphenyl Ether (PBDE)
- Exempt Tetrabromobisphenol A (TBBPA)
Electronic Equipment Affected by RoHS

Appliances
Tools
IT Equipment
Telecommunications Equipment
Lighting
Toys
Sports equipment

Currently RoHS exempt
- Medical Devices
- Monitoring and Control Instruments

Household Appliances
IT and Telecommunication Equipment
Lighting Equipment

UL the standard in safety
Lead-free Processing Challenge

Lead-free materials require 30°C to 45°C higher melting temperatures when compared to tin-lead solder.

Soldering Material Melting Points and Associated Solder Pot Temperatures

<table>
<thead>
<tr>
<th>Material</th>
<th>Melting Range (°C)</th>
<th>Solder Pot Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn-Pb</td>
<td>183 – 188</td>
<td>250</td>
</tr>
<tr>
<td>Sn-Cu (99.3Sn/0.7Cu)</td>
<td>227</td>
<td>270 – 280</td>
</tr>
<tr>
<td>Sn-Ag-Bi</td>
<td>206 – 213</td>
<td>260</td>
</tr>
<tr>
<td>Sn-Ag-Cu</td>
<td>217</td>
<td>260 – 270</td>
</tr>
<tr>
<td>Sn-Ag (96.5Sn/2.5Ag)</td>
<td>221</td>
<td>265 – 275</td>
</tr>
</tbody>
</table>
Lead-free Processing Challenge

Lead-free temperatures reduce the process tolerance
  • Tin/Lead reflow 225°C
  • Lead-free reflow 245°C+
  • Component max temp 260°C

Tolerance reduced by more than 50%
  • 15°C for lead-free instead of 35°C for tin/lead

Affects both PWB mfrs and Assemblers
Higher Temperatures

**Potential problems in the PWB**
- Delamination and warping
- Thermal shock induced cracks
- Damage to the components, such as
  - Plastic connectors, relays, LEDs, electrolytic and ceramic capacitors, etc.

**Modifications required in process to**
- Prevent damage from higher temperatures
- Wetting and solder joint formation problems
- Overheating the assembly and components
Potential Solutions to Lead-free Challenges

Pre-selection of materials and PWBs

- Select alternate materials with higher temperature ratings for soldering process

- Select PWBs proven to be Lead-free compatible
How to Reduce Time to Market When Selecting Alternate Materials
UL iQ for Printed Wiring Boards

Welcome to UL's iQ for Printed Wiring Boards Database

UL's iQ for Printed Wiring Boards includes materials covered under the following categories:

- **Component - Printed Wiring Boards** (ZPMV2)
  - This category covers printed wiring boards for use as components in devices or appliances. The boards may use organic or inorganic base materials in a single or multilayer, rigid or flexible form. Circuitry construction may include etched, die-stamped, precut, push press, additive, and plated conductor techniques. Printed-component parts may be used.

- **Component - Laminates** (QMTS2)
  - This category covers materials that have been tested in accordance with established methods to define their properties in order to facilitate investigation of their use in end-product applications. These materials may consist of filament-wound tubing, industrial laminates, braided fiber, and other materials for use in fabricating Recognized printed wiring boards.

- **Component - Flexible Printed Wiring Boards** (ZPXK2)
  - This category covers printed wiring construction incorporating flexible materials for use as components in devices or appliances. Flexible materials are defined as films or materials exhibiting flexible properties. The constructions may use flexible materials in a single or multilayer build-up and in combination with additional flexible or rigid materials. Flexible material constructions may employ etched, die-stamped, precut, pushpress, additive plated conductors, polymer thick film, dual access, cast and adhesiveless techniques. Printed-component parts may be used.

- **Component - Coatings for use on Printed Wiring Boards** (QMJU2)
  - This category covers permanent coatings for use on Recognized printed wiring boards. These coatings may consist of solder resist (solder mask) or conformal coatings.

The materials covered in this database are incomplete in certain constructive features or restricted in performance capabilities and are intended for use as components of complete equipment submitted for investigation rather than for direct separate installation in the field. THE FINAL ACCEPTANCE OF THE COMPONENT IS DEPENDENT UPON ITS INSTALLATION AND USE IN COMPLETE PRODUCTS SUBMITTED TO UNDERWRITERS' LABORATORIES INC.
UL iQ - PWB Parametric Search

UL iQ for Printed Wiring Boards

- Conductor Attributes
  - Min Width
  - Min Edge
  - Max Area Diam

- Solder Time (sec)
- Max Solder Temp (C)
- Max Ext Thk
- Max Int Thk
- Max Ext Thk

- Meets UL 746 DSR
- n/a

- Comparative Tracking Index (CTI)
- n/a

- Max Operating Temperature
- n/a

- Flame Class
  - n/a
  - equato
  - single shielded
  - double or single shielded

- Construction Type
  - n/a

- Company Name

- additionally certified in accordance with Canadian National requirements

- UL 746 DSR

- n/a

- Single shielded

- Double or single shielded

- Surface Mount

- Printed Wiring Boards

- Search

UL - the standard in safety
CMK CORP  
1106 FUJIKUBO, MIYOSHI-MACHI, IRUMA-GUN SAITAMA-KEN 354-8580 JP  
CA10  
Multilayer printed wiring boards  

<table>
<thead>
<tr>
<th>Cond Width</th>
<th>Cond Width</th>
<th>Cond Thk</th>
<th>Cond Thk</th>
<th>Cond Thk</th>
<th>Max Int (mic)</th>
<th>Max Ext (mic)</th>
<th>Max Area</th>
<th>Solder Limits</th>
<th>Solder Limits</th>
<th>Max Oper</th>
<th>Temp Oper</th>
<th>Flame Class</th>
<th>Meets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min (mm)</td>
<td>Edge (mm)</td>
<td>Min (mic)</td>
<td>9</td>
<td>35</td>
<td>102</td>
<td>DS</td>
<td>25.4</td>
<td>180</td>
<td>900</td>
<td>130</td>
<td>180</td>
<td>V-0</td>
<td>UL796</td>
</tr>
<tr>
<td>0.03</td>
<td>0.03</td>
<td>9</td>
<td>102</td>
<td>DS</td>
<td>25.4</td>
<td>900</td>
<td>130</td>
<td>180</td>
<td>360</td>
<td>360</td>
<td>180</td>
<td>V-0</td>
<td>UL796</td>
</tr>
</tbody>
</table>

Report Date: 1991-01-03  
Last Revised: 2006-06-20  

Underwriters Laboratories Inc®
Two pre-selection programs for materials

• Metal Clad Industrial Laminate (MCIL or CCIL)
• Permanent Coatings Program

Allow generically similar materials to be characterized as suitable for cross substitution without re-evaluation in the PWB.
UL iQ - Laminate Parametric Search
## Pre-selection Criteria for MCIL Addition of Alternate Laminates

<table>
<thead>
<tr>
<th>Laminate Parameter</th>
<th>Certification Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) UL category code (CCN)</td>
<td>Recognized QMTS2 industrial laminate</td>
</tr>
<tr>
<td>(2) UL/ANSI laminate type</td>
<td>Recognized with the same UL/ANSI type (FR-4, CEM-1, and CEM-3 are considered equivalent; all other UL/ANSI types are distinct.)</td>
</tr>
<tr>
<td>(3) Minimum laminate thickness</td>
<td>Recognized with the same or thinner thickness (Ultrathin laminate and prepreg materials for use in multilayer PCBs require a minimum of delamination testing.)</td>
</tr>
<tr>
<td>(4) Minimum cladding thickness (copper weight)</td>
<td>Recognized with the same or thinner thickness copper (MCIL program does not apply to unclad laminates.)</td>
</tr>
<tr>
<td>(5) Maximum cladding thickness (copper weight)</td>
<td>Recognized with the same or greater thickness copper</td>
</tr>
<tr>
<td>(6) Number of sides clad</td>
<td>Double sided constructions represent single sided constructions for rigid PCBs</td>
</tr>
</tbody>
</table>

Continued on next slide
Pre-selection Criteria (cont’d) for MCIL Addition of Alternate Laminates

<table>
<thead>
<tr>
<th>Laminate Parameter</th>
<th>Certification Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>(7) Maximum area diameter unpierced (MAD)</td>
<td>Recognized with a minimum 50.8mm which represents larger areas</td>
</tr>
<tr>
<td>(8) Solder limits</td>
<td>Recognized with a) the same or greater temperature and b) the same or longer dwell time</td>
</tr>
<tr>
<td>(9) Maximum operating temperature (MOT)</td>
<td>Recognized with the same or greater temperature</td>
</tr>
<tr>
<td>(10) Flammability rating</td>
<td>Recognized with the same or better flame rating</td>
</tr>
<tr>
<td>(11) Meets Direct Support (DSR)</td>
<td>Yes, if required by the end product</td>
</tr>
<tr>
<td>(12) Comparative tracking index (CTI)</td>
<td>Recognized with appropriate performance level (PLC) if required by the end product</td>
</tr>
</tbody>
</table>
Advantages of UL Recognition

Materials included in iQ database are covered under UL’s Component Recognition Program

- Type Testing
  - Provides user with confidence that the component initially complies with requirements
- On-going compliance (FUS – Follow-up Service)
  - Audit Surveillance of materials and PWBs during production
  - Provides user with confidence that the component continues to meet these requirements moving forward
Summary

✓ Lead-free requires higher temperatures

✓ iQ database enables users to locate suitable materials/PWBs for higher temp applications

✓ Pre-selection programs eliminate the need to test each material in each specific part configuration

✓ Faster qualification of alternate materials

✓ Confidence that the materials continue to meet requirements (type testing and on-going verification)

✓ Faster time to market
Thank You

Questions?