

# FR-4 Reclassification

**Presented by:**  
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  - Electrical and Electronic Insulating Materials
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# 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)

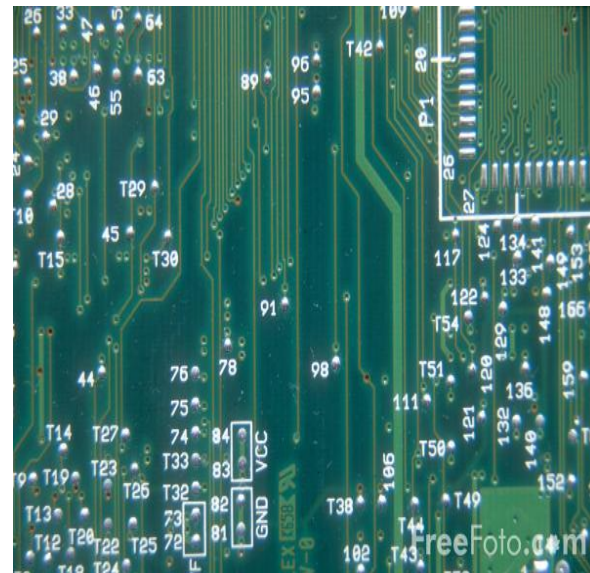
Official IPC term is currently “Printed Boards”

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 through-out this presentation for PBs.



# Agenda

- UL Background
- Characterization of Printed Wiring Boards (PWBs)
  - Hazards in the End Product
  - Abbreviated Test Programs
- History of FR-4 Laminate
- Proposal to Reduce Testing
- Risk if No Action



# Who is UL?

Underwriters Laboratories Inc.

- Independent, not for profit, safety testing and certification organization

Global leader in product safety

- Promote safe living and working environments by the application of safety science and hazard-based safety engineering
- Support production and use of products physically and environmentally safe
- UL name and marks are known and trusted around the globe



End-Product Listing Mark



Component Recognition Mark



# Who is UL?

Leader in standards development, testing and certification  
working together with industry

- PWB Safety Standards
- WECC members

1894  
UL founded



1957  
IPC

1962  
JPCA

1968  
EIPC

1985  
IPCA

1990  
CPCA

1998  
TPCA

2000  
HKPCA

2003  
KPCA

Today

1965  
UL 796

1972  
UL 94

1985  
UL 746E

2000  
UL 796F

2006  
UL 746F



# Who is UL?

## 175 Staff globally dedicated to material evaluations

- Asia: China, Hong Kong, India, Japan, Korea, Taiwan
- US: California, Illinois, New York, North Carolina, Washington
- Europe: Denmark, Italy, Netherlands, United Kingdom

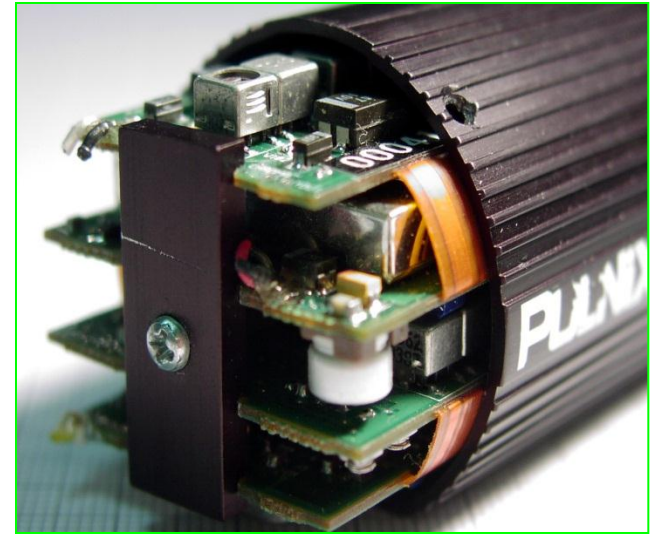
## Materials testing labs

- Taiwan
- US (San Jose and Melville)
- Denmark
- Germany



# UL Aims to Reduce Risks

- Fire
- Electric Shock
- Personal Injury
- Environmental Hazards



Comply with International and North American safety standards





# “Hazard-Based” Engineering Approach

## HBSE – Hazard Based Safety Evaluation

- Analyze the installation
  - Location and intended use
  - Attachment systems, wiring systems
  - Hazards
- Analyze the product
  - Materials
  - Construction
  - Hazards



# PWB Hazard Based Evaluation

PWB safety hazards in the end product

- Risk of electric shock
- Risk of flammability



# PWB HBSE – Risk of Electric Shock

## Risk of electric shock due to spacing/insulation deficiencies

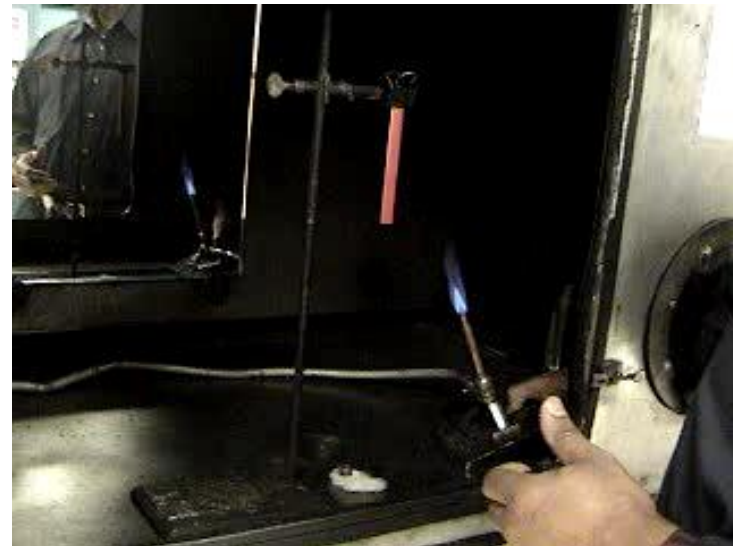
- Reduced Spacings
  - Conductor adhesion
  - Delamination, warping or cracking
  - Tracking
  - Silver migration
  - Plating adhesion
- Insulation Breakdown
- Mechanical Strength Deficiency
  - Ability to support components



# PWB HBSE – Risk of Flammability

## Risk of flammability

- Fuel for fire and increased burn time
  - Coatings without flame retardant - solder resist, plugged hole and marking material
- Ignitability
  - Hot wire exposure
  - Arcing exposure



# Why UL PWBs?

## PWB certification driven by end-product requirements

- Many end-product standards require UL Recognized PWBs, for example:
  - IEC 60950 (Information Technology Equipment)
    - V-1 flame, MOT for application, and direct support
  - IEC 60601 (Medical Equipment)
  - IEC 60065 (Audio & Video Equipment)
  - IEC 60335 (Appliances)

Using Recognized materials and components can significantly reduce testing for OEMs



# Pre-selection

The process of assessing and choosing materials and PWBs for electrical products.



# Advantages of Pre-selection

- Aides in material and PWB selection during the design stage
- Compare and evaluate 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



# Background for UL/ANSI Laminate

UL/ANSI laminate types based on

- Chemistry and performance
- Characterization of material for use in PWBs

Benefits of classification system

- Industrial Laminate Abbreviated Test Program
- PWB MCIL/CCIL (Metal Clad Industrial Laminate) Test Program
- PWB Permanent Coatings Program

Fundamental assumption of abbreviated testing programs:

- Characterization criteria demonstrates that one material performs similarly to another (no additional testing required)

Characterization criteria must be maintain to allow the benefits of these programs to continue





# PWB MCIL / CCIL Test Program

## Reduced / No-Test Program for Recognized PWBs

### MCIL / CCIL Program

- Addition of laminate and laminate/prepreg packages to existing boards
- Assumes each UL/ANSI material has the same performance
- Metal-clad laminate parameters need to be equal or more severe than PCB being added to
- Single-layer materials waive all testing
- Multi-layer materials waive all testing but delamination-only
- Multi-layer core materials to HDI boards waive all testing but delamination-only



# PWB Permanent Coatings Program

## No-Test Program for Recognized PWBs

### Permanent Coatings Program

- Solder resist additions to existing boards
- Assumes each core UL/ANSI material has the same performance
- Solder resist to have equal or more severe parameters than PWB being added to
- No testing to add to single or multi-layer boards



# FR-4 History and Definition

FR-4 created in 1968 with NEMA

- Six IR reference scans
- NEMA – National Electrical Manufacturers Association

Scans represent industry intent at the time

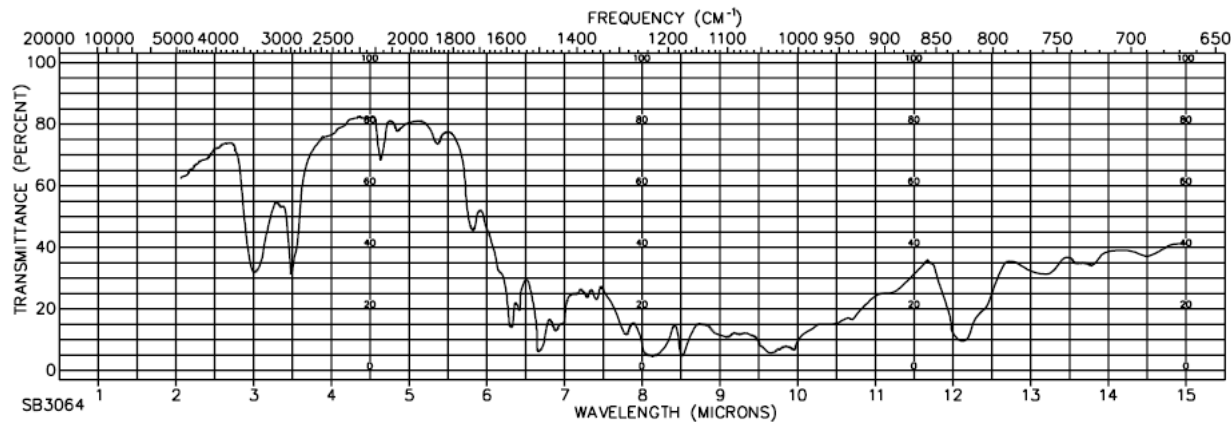
- Epoxy resin
- Brominated flame retardant
- Dicy curing agent
- No filler
- Woven glass fabric reinforcement



# FR-4 Survey Project – What is FR-4?

1996 UL/IPC Project intended to address

- Poor quality of original six (6) FR-4 reference scans
- Modified FR-4 materials - “what is an FR-4?”
- Do modified materials reflect the traditional FR-4 definition?



# PWB Evaluation Risks for FR-4

## Past and future FR-4 performance

- All current FR-4 materials do not represent each other for the purpose of testing
- Some FR-4s are less thermally stable
- Some FR-4s are more thermally stable
  - Higher lead-free processing temperatures
- Delamination can be affected by brittle resins and filler
- Bond strength can be affected by resin type and filler



# PWB Evaluation Risks for FR-4

Flame retardants react through either physical or chemical means.

- Bromine – oxygen scavenger
  - Phosphorus – carbon layer
  - Aluminum Hydroxide – water vapor
- 
- PWB flame retardant comes from the base material
  - FR-4s contain different flame retardant systems
  - Solder resists do not always include flame retardant
  - Most solder resists evaluated on brominated FR-4 only



# Standards Development

UL certifies products and is instrumental in the development and recommendations for maintaining Safety Standards

Writing and maintaining Safety Standards is a collaboration exercise

- UL experts, manufacturers, industry groups, product consumers
- Controlled by the Standards Technical Panel (STP)
  - UL has only one vote within each STP
- STP participation and membership information available at:  
[http://ulstandardsinfolnet.ul.com/stp/call\\_4\\_members.html](http://ulstandardsinfolnet.ul.com/stp/call_4_members.html)



# STP Representative Categories

## Supply Chain:

- Component producers for standards covering end-products

## Commercial/Industrial User:

- Organizations that use the product in a commercial or industrial setting

## AHJ (Authority Having Jurisdiction):

- Regulation or enforcement organizations of the code and standard requirements at a regional (e.g. state or province) and/or local level

## Government:

- Representatives from national government agencies.

## Testing and Standards Organization:

- Organizations that test and/or certify products

## International Delegate:

- International delegate is an individual representing a National Standards Body outside of the United States (e.g. JISC, DIN). This person is designated by the National Standards Body and approved by the STP Chair





# UL796 / UL746E STP Members

Name	Company	Interest Category
TAKAHISA AKATSUKA	NIPPON MEKTRON LTD	Non voting member
FRANK BAI	TAIWAN PRINTED CIRCUIT ASSOCIATION	General
MICHAEL BEAUCHESNE	AMPHENOL PRINTED CIRCUITS INC	Producer
J BRAMEL	JACK BRAMEL ASSOCIATES	General
JOSEPH DAVIS	ROGERS CORP	Producer
THOMAS GARDESKI	GEMINI SCIENCES	General
JANE GUAN	GUANGDONG SHENGYI SCI TECH CO LTD	Producer
TORU KOIZUMI	JPCA ELECTRONICS PACKAGING & CIRCUITS ASSOCIATION	General
JEFFREY LEE	IST-INTEGRATED SERVICE TECHNOLOGY	Testing & Stds Org
TZONG-MING LEE	INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE	Government
J LIU	BOARDTEK ELECTRONICS CORP	Producer
Derrick L. Martin	Underwriters Laboratories Inc.	Project Manager
YOSHINOBU MARUMOTO	JAPAN THERMOSETTING PLASTICS	General
B NEVES	MICRO TECHNICAL LABORATORIES, DBA MICROTEK LABORATORIES	Testing & Stds Org
T NEWTON	IPC-ASSOCIATION CONNECTING ELECTRONICS INC	Testing & Stds Org
Bradley J. Schmidt	Underwriters Laboratories Inc.	Chair
DOUGLAS SOBER	KANEKA TEXAS CORP	Producer
DAVE SOMMERVOLD	BERGQUIST CO	Producer
VALERIE ST CYR	TERADYNE INC	Commercial-Ind. User
TOMOMI UJIIE	CHEMITOX INC	Testing & Stds Org
Crystal E. Vanderpan	Underwriters Laboratories Inc.	Testing & Stds Org



# UL746E Standard Revised by STP

## Add new IR reference scans for FR-4

- Based on 1996 UL/IPC project
- Include FR-4s with Dicy and Phenolic curing agents
- 14 IR reference spectra instead of 6
- To maintain UL796 PWB CCIL and Solder Resist programs

## UL746E, Paragraph 8.7

- 8.7 A material with **non-compliant IR spectra fundamental variations** qualifies for additional testing including full performance profile indexing and two or four point thermal aging as described in the Full Test Program, Section 9. **The material shall not be given a UL/ANSI type designation.**



# QMTS2 FR-4 File Review

## Important Letter dated October 4, 2001

- All Recognized FR-4s compared with new 14 UL/ANSI FR-4 IR reference spectra

## File review results

- 270 Recognized FR-4s
- 81 materials did not match FR-4 reference
- Need to create new ANSI groups

## Laminate manufacturers requested to provide

- Description of resin system, curing agent, flame retardant, fillers, and reinforcement materials



# UL Working to Reduce Impact

Postponed FR-4 file review effective date

Industry meetings to develop laminate and PWB solutions

- UL/ANSI groups
- PWB reduced testing programs

Research to find test methods for material compatibility

- Time to Delamination (T260)
- Oxygen Index

FR-4 file review must be completed due to published UL746E standard requirements



# FR-4 Research Timeline

- 1996 – UL and IPC FR-4 Project – What is FR-4?
- 1999 – Review FR-4 results for possible grouping
- 2001 – Proposal to update UL746E with new FR-4 IR spectra
- 2001 – FR-4 laminate file review begins
- 2002 – UL begins work with JTPIA and IPC to develop compatibility test program
- 2003 – Industry requests UL to develop program for filled FR-4s
- 2003 – 2004 Time to delamination (T260) test evaluated with IPC and JTPIA
- 2004 – File review effective date postponed due to high number of noncompliant FR-4s
- 2005 – Announcement of FR-4 Reclassification sent to industry STP and Subscribers of standards UL746E and UL796
- 2006 – Review of JTPIA FR-4 grouping, test data needed
- 2007 – Report on Oxygen Index and Td Leadfree UL research
- 2007/ 2008 – UL/IPC/JPCA joint meetings at JPCA show in Tokyo, Japan
- 2008 – FR-4 STP task group teleconference to finalize grouping proposal
- 2008 – Meeting with Taiwan laminate manufacturers regarding FR-4 grouping
- 2009 – UL and JTPIA FR-4 Reclassification teleconference
- 2010 – IPC, JPCA, TPCA discussions regarding FR-4 Reclassification.



# Search for Equivalency Tests

## Time to Delamination (T260) test

- Test is not reproducible in different labs
- Must use a control material
- Control material varies based on materials tested
- Mixed dissimilar materials – 2 controls needed (one of each pure material)

## Oxygen Index test (ASTM D2863)

- Can not establish relationship between UL94 flammability classification and oxygen index
  - Solder Resist – Epoxy and Acrylic
  - FR-4 Laminates – Traditional, Epoxy blend, Filled, Halogen Free



# Options to Resolve FR-4 Issue

1. Classify all Epoxy materials as FR-4
2. Maintain traditional FR-4s only
3. Reclassify FR-4 based on performance only
4. Reclassify FR-4 based on chemistry and performance



# Impact to Industry

<b>Option 1</b>	<b>Classify all Epoxy materials as FR-4</b>			
Industry	Laminate	Solder Resist	PWB	End Product
Impact	No File Review	<b>File Review</b>	<b>File Review</b>	Specify individual PWBs
	Abbreviated program discontinued	Solder Resist program discontinued	CCIL and Solder Resist program discontinued	
	<b>LTTA on all new material</b>	<b>Flame testing on each material</b>	<b>Full testing on all laminates and solder resists</b>	





# Impact to Industry

<b>Option 2</b>	<b>Maintain traditional FR-4s only, other epoxy based materials Non-ANSI</b>			
Industry	Laminate	Solder Resist	PWB	End Product
Impact	<b>File Review, epoxy based now Non-ANSI</b>	No File Review	<b>File Review</b>	Specify traditional FR-4 PWBs only
	Abbreviated program maintained	Solder Resist program maintained	CCIL and Solder Resist program maintained	Specify non-ANSI as individual PWBs
	<b>LTTA if IR non-compliant, Recognized Non-ANSI</b>	<b>Option to test on Non-ANSIs</b>	<b>Full testing Non-ANSI laminates with all solder resists</b>	



# Impact to Industry

<b>Option 3</b>	<b>Reclassify FR-4s based on performance only</b>			
Industry	Laminate	Solder Resist	PWB	End Product
Impact	<b>File Review</b>	<b>File Review</b>	<b>File Review</b>	Specify individual PWBs
	Abbreviated program discontinued	Change Solder Resist program to performance	Change CCIL and Solder Resist program to performance	
	Unable to determine test program	Unable to determine test program	<b>Test based on performance of all laminates</b>	
	<b>LTTA on all new materials</b>	<b>Flame testing on all materials</b>	<b>Test based on performance of all solder resists</b>	



# Impact to Industry

<b>Option 4</b>					<b>Reclassify FR-4s based on chemistry and performance</b>			
Industry	Laminate	Solder Resist	PWB	End Product				
Impact	<b>File Review to rename materials</b>	No File Review	<b>File Review</b>	Specify FR-4 and new ANSI group PWBs				
	<b>Abbreviated program maintained for existing and new ANSI groups</b>	<b>Solder Resist program maintained for existing and new ANSI groups</b>	<b>CCIL and Solder Resist program maintained for existing and new ANSI groups</b>	Specify non-ANSI as individual PWBs				
	<b>LT TA on new material if IR non-compliant with new ANSI groups</b>	<b>Option to test new ANSI groups and Non-ANSI materials</b>	<b>Test laminates changed to Non-ANSI with each solder resist</b>					



# Proposed New UL/ANSI Groups

UL/ANSI Type	Primary Resin	Secondary Resin	Filler	Curing Agent	Flame Retardant	Reinforcement
<b>FR-4 @1</b> <b>Current Definition</b>	Epoxy	None	None	Dicy or Novolac	Bromine	Woven Glass
<b>FR-4F @1</b> <b>(proposed filled FR-4)</b>	Epoxy	None	Inorganic Max 30%	Dicy or Novolac	Bromine	Woven Glass
<b>FR-4G (FR-7) @2</b> <b>(proposed Low-Halogen FR-4)</b>	Epoxy	None	None	Dicy or Novolac	Phosphorus	Woven Glass
<b>FR-4GF (FR-7F) @2</b> <b>(proposed Low-Halogen filled FR-4)</b>	Epoxy	None	Inorganic Max 30%	Dicy or Novolac	Phosphorus and Aluminum Hydroxide	Woven Glass
<b>FR-4B (FR-8)</b> <b>(proposed Polymer Blend FR-4)</b>	Epoxy	Cyanate Ester	None	Dicy or Novolac	Bromine	Woven Glass

@1 - Types considered equivalent for MCIL and Permanent Coatings PWB programs.

@2 - Types considered equivalent for MCIL and Permanent Coatings PWB programs.

Inorganic filler – Includes Silica, Clay, Talc, Ceramic, Calcium Carbonate, Aluminum Hydroxide, Cab-O-Sil (Mica?), Titanium Oxide



# Summary

## Intent of PWB CCIL and Coating programs

- Reduced testing programs for PWBs based on assumption that each UL/ANSI material performs the same
- Pre-selection programs

## Enhanced Epoxy laminates do not perform same

- Large amount of research available from industry

## Lead-free processing requires higher temps

- Past performance can't predict the future

## Reclassification based on characterization and performance criteria

- Demonstrates equivalence to allow FR-4 reduced testing in PWBs



# Proposed Timeline for File Review

Written proposal to STP	April 2011
Comment deadline	30 days
Ballot proposal	30 days
Publish requirements	3 months
Laminate IFR effective date	2 years
Solder resist IFR effective date	2 years
PWB IFR effective date	4 years





**Thank you**

**Questions?**