iNEMI

International Electronics Manufacturing Initiative

iNEMI
Halogen-Free Project
Phase 1 Review

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Halogen-free Project

Overall Project Objectives:

- Build on industry knowledge and capability,
- Consider unique market segment requirements,
- Identify technology readiness and gaps,
- Stimulate supply capability, and
- Recommend standards development opportunities

Is / Is Not

This Project IS	This Project Is NOT
Technical evaluation of key electrical and mechanical properties	EHS assessment
Focused on those attributes which are of most value to supply chain.	Biased towards specific laminate suppliers, geographies, or market segments.
Build on learning from prior investigations	Repeat of prior work
Recommendations for standards development or further investigation	Standard Development
Focused on circuit board	Electronic components, Cables

Proposed Schedule

Phase I (Design)	**Feb 1 ’06 – Sept 30 ’06**
Phase II (Test)	**Oct 1 ’06 – June 30 ’07**
Phase III (Results)	**July 1 ’07 – Nov 30 ’07**
Release Results	**Dec ‘07 (iNEMI members)** **Feb ’08 (APEX-Public summary)**

Anticipated Outcomes

1. **Define electrical requirements based on market segment application**

2. **Validate electrical and mechanical properties**
   - **Loss tangent and Dk modeling over required range of signal speed**
   - **Mechanical performance validation for lead free assembly**

3. **Validate material supplier and PCB manufacturer infrastructure capability**

4. **Estimate costs – volume market leader for new material may not achieve cost parity with best-in-class FR4**

3 –Phased Approach

Phase 1: Design

Goal: *Review prior work and make recommendations for testing needed. Investigation should take into account the needs of electronic product sectors represented by iNEMI membership.*

- **Identify market segment requirements**
- **Identify candidate materials (synch with EPA)**
- **Identify key performance characteristics and test criteria**
- **Design test vehicle(s) and test methodologies, leverage standards where possible**

Phase 2: Test

Goal: *Develop, manage, and execute performance testing*.

- **Develop evaluation schedule**
- **Procure parts and test vehicles**
- **Assign teams to carry out completion of the testing in a standardized fashion**
- **Perform mechanical and reliability testing on test vehicles.**

Phase 3: Results

Goal: *Compile results, assess significance, make recommendations, and publish report.*

- **Assess performance relative to market segment requirements.**
- **Assess technology readiness / identify gaps**
- **Assess manufacturing capability and supply capacity**
- **Publish results**

Phase 1 Review

- Task 1 – Define Market Segment Requirements
- Task 2 – Identify Candidate Materials
- Task 3 – Identify Key Performance Characteristics and Test Criteria

Phase 1 – Task 1

Define Market Segment Requirements

Task 1: Segment Requirements

Objective: **Consult iNEMI PEGs to identify unique HF requirements for product sectors**

1) **Identify market segment requirements**

2) **Determine segment readiness and gaps**

3) **Identify standards development opportunities**

Insufficient Input from membership to determine segment requirements / readiness

Phase 1 – Task 2

Identify Candidate Materials

Task 2: Identify Candidate Materials

- **Objectives**
  - **Review Prior Studies**
    - **Identify Materials Used**
    - **Recognize Gaps/Issues With Current Data**
  - **Review Existing Literature / Fabricator Use**
    - **Broad Supplier Representation**
    - **Applicable Market Segments**
    - **Represent Different Laminate Manufacturer's Resin Formulations**
    - **Likelihood of success**
  - **Obtain Supplier Agreement to Provide / Work With Candidate Materials**
    - **Success Highly Dependant on Using Fabricators With Experience With Identified Materials.**
  - **Recommend Materials For Subsequent Assessment**

Task 2: Identify Candidate Materials

- **Team Identified Materials Based on Information Available in The Industry and Through Laminate Supplier Consultation.**

- **Target Is to Have a Varied Cross Section of Laminate Material Suppliers, Geographies, and Chemistries Represented.**
  - **Identified 30 Candidate Halogen Free Laminate Materials From 15 Manufacturers**
  - **Eight (8) Laminates From 6 Suppliers Were Identified As Primary Candidates For Assessment.**

- **Materials Were Chosen Which Are Purported to Have a Reasonable Chance of Surviving Full Pb-free Assembly Process Conditions Within Their Target Market Segment / Design Point.**

Task 2: Identify Candidate Materials

Laminate Supplier	Material	Country of Manufacture
NanYa	NPG-R	Taiwan / China
	NPG-TL / NPG-170TL *	
Hitachi	BE-67G(H)	Japan / Hong Kong / China
	E-679FG *	Japan
	EX-77G	? Japan ?
Elite Materials Co	EM280	China
Isola	IS500 *	Italy
	DE156	Germany, Taiwan
	HF571 (formally Polyclad) *	Germany, Taiwan
Nelco	4000-7EF *	Singapore
LG Chemical	LG-E(B) 481	Korea

Laminate Supplier	Material	Country of Manufacture
TUC	TU-642	Taiwan
ITEQ	IT155G	Taiwan
	IT140G	Taiwan
	IT170G * (??)	
Mitsubishi	CCL-EL150	Japan
Panasonic / MEW	R1566	Japan/Taiwan/China
	R1515T *	Japan
	R1515B	
Ventec	VT44	China
Grace	GAHF14 / GAHFR / GAHFTL *	China
Doosan	DS7402 (H) *	South Korea
	DS7402	South Korea
Guangdong Shengyi	S1165 *	China
Sumitomo Bakelite	ELC-4785GS / ELC-6785GS / ELC-4765GF	Japan

Materials To Be Assessed

Material	Handheld	PC	Server	Country of Manufacture
NanYa NPG-TL	X	X		Taiwan/China
NanYa NPG-170TL			X	Taiwan/China
Hitachi BE-67G(J)	X	X	x	Japan/HK/China
Isola DE156	X	X		Germany / Taiwan
Isola IS500			X	Italy
TUC TU-642	X	X		Taiwan
MEW R1566W	X	X	x	Japan/Taiwan/China
ITEQ IT170G		X	X	Taiwan/China

Handheld:	4 - 6 layers, 50 mils
PC:	12 - 14 layers, 75 mils
Server:	24 - 26 layers, 150 - 160 mils

Note : **"X"** is definite candidate **"x"** Tentative Candidate based on Test Volume Capability

Phase 1 – Task 3

Identify Key Performance Characteristics and Test Criteria

Task 3: key performance characteristics and test criteria

- **Objectives**
  - **Assess prior studies and identify critical knowledge gaps**
    - Review results of prior industry studies and member company investigations
  - **Identify potential technical issues**
  - **Recommend performance test requirements based on market segment needs**
    - Identify Pre-screening evaluation
    - Agree on Functional Testing

- **Proposed Test Strategy**
  - **Screening of Materials**
    - Evaluation of electrical, physical and **thermal properties** of commercially available Halogen-free laminate materials. Materials passing the initial screen will go to Phase II, which is building of test vehicles to evaluate other material properties. (see next slide)
    - Determination of **propensity for failure (ie, delamination, via fatigue degradation)** in the Pb-free process environment on a per-application basis.
      - Pb-free on thinner / less thermally massive applications at up to 245 C (4-10 layer)
      - Pb-free on more thermally massive applications at up to 260 C. (12 – 24 layer)
      - The third party lab evaluates these boards per IPC 6012B Class 2 (if deemed necessary)

Physical Properties Data

Property Tested	Test Method	Acceptable	Ideal
Dielectric constant 1-2.5 GHz	2.5.5.6 (IPC-TM-650)	< 4.5	< 3.3
Loss factor @ 1 MHz	2.5.5.6 (IPC-TM-650	< 0.017	< 0.007
Glass transition temperature, DSC (C	2.4.25 (IPC-TM-650)	> 180	>200
Glass transition temperature, TMA (C)	2.4.24.5 (IPC-TM-650)	> 180	>200
Decomposition temperature, TGA (C)		> 300	> 350
Time to delamination (min@260/288 C)	2.4.24.1A (IPC-TM-650)	> 60	> 120
Flammability	C-H 6-0430-102	V0 – Br-free	V0 – Br-free
Pressure cooker test (min)	2.6.16 (IPC-TM-650)	> 30	> 120
Moisture, 24hr/RT (Wt% Gain)	2.6.2.1 (IPC-TM-650)	< 0.3	< 0.1
Moisture, 1hr/PCT (Wt% Gain)	ASTM D570 (E 1/105 and D 24/23)	< 1.0	< 0.5
Cu Peel (lb/in)	2.4.8.2 (IPC-TM-650)	> 5	➢10
Sticker ILB (lb/in)		> 3	➢6
Oxide ILB (lb/in)		> 2	➢5
CTE (ppm/C) X, Y below Tg	2.4.41 (IPC-TM-650)	16 - 18	16 - 18
CTE (ppm/C) Z below Tg	2.4.41 (IPC-TM-650)	~ 60	30
CTE (ppm/C) X, Y above Tg	2.4.41 (IPC-TM-650)	5 - 8	5 – 8
CTE (ppm/C) Z above Tg	2.4.41 (IPC-TM-650)	300	150

- **Proposed Test Strategy**
  - **Electrical Evaluation (< 20GHz)**
    - **Dielectric Constant (1MHz / 1GHz / 10GHz / Higher ?)**
    - **Dissipation Factor (1MHz / 1GHz / 10GHz / Higher ?)**
    - **Surface Insulation Resistance (before solder mask)**
    - **Dielectric Voltage Breakdown (Dielectric Withstanding)**
  - **Mechanical Evaluation**
    - **Tg**
    - **T-260 / T-288**
    - Cross Sections
    - Line width & spacing
    - **Hole to Pad Registration**
    - **Peel Strength**
    - **Bend Test**
    - **Reliability**
      - **CAF**
      - **IST**
      - **HATS**
      - **Shock / Drop (based on market segment requirements?)**

- **Proposed Stack Ups (Depending on which segments selected)**
  - **High and Low Resin Content**
    - **HandHeld : 1-4-1 / 2-2-2 < 1mm**
    - **Mobile : 1-8-1 / 8-10 layer < 1mm**
    - **Desktop : 4 – 8 layer < 1.5mm**
    - **Server : 8 – 24 layer 2-3 mm**
  - **Control Materials (or similar – Choose one)**
    - **Isola IS410**
    - **Polyclad Turbo 370**
    - **Nelco-4000-6**
    - **Nanya NP170**

Test Vehicle

- **Possible Test Vehicles**
  - **Screening / Characterization**
    - Pb-free Compatibility
    - IBM Short Pulse Propagation Method
  - **Full Reliability Testing**
    - Intel Materials Evaluation Board

Path Forward

Path Forward

- **Requirements for Completion of Phase 1 :**
  - **Determination of appropriate pre-screen testing and desired results**
    - **Identification of appropriate functional testing based on market segment requirements**
    - **Agreement on pass / fail criteria based on market segment requirements**
    - **Assess / address manufacturability impacts (drillability, plateability, adhesion etc)**
  - **Market Segment Differentiation / Criteria**
  - **Resource Requirements**
    - **Review team of materials / PCB engineers from various market segments to assess information gaps, identify potential risks associated with HF materials**
    - **Test / PCB engineers from various market segments to identify critical test parameters / functional tests to be performed**

Next steps: Q4 2006

Commence Phase 2

- Identify participants and team leads
- Set up meeting schedules / logistics
  - Review Original Schedules and update as needed
- Identify Fabricators / Build Test Vehicles
- Identify Test Methods
- Identify who will perform the required testing

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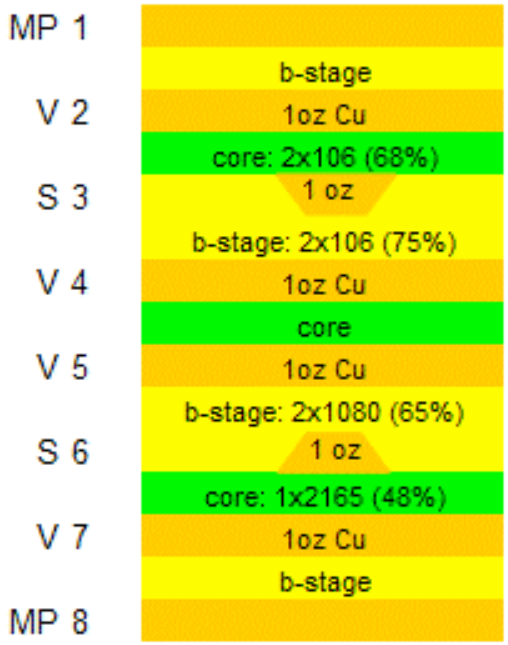
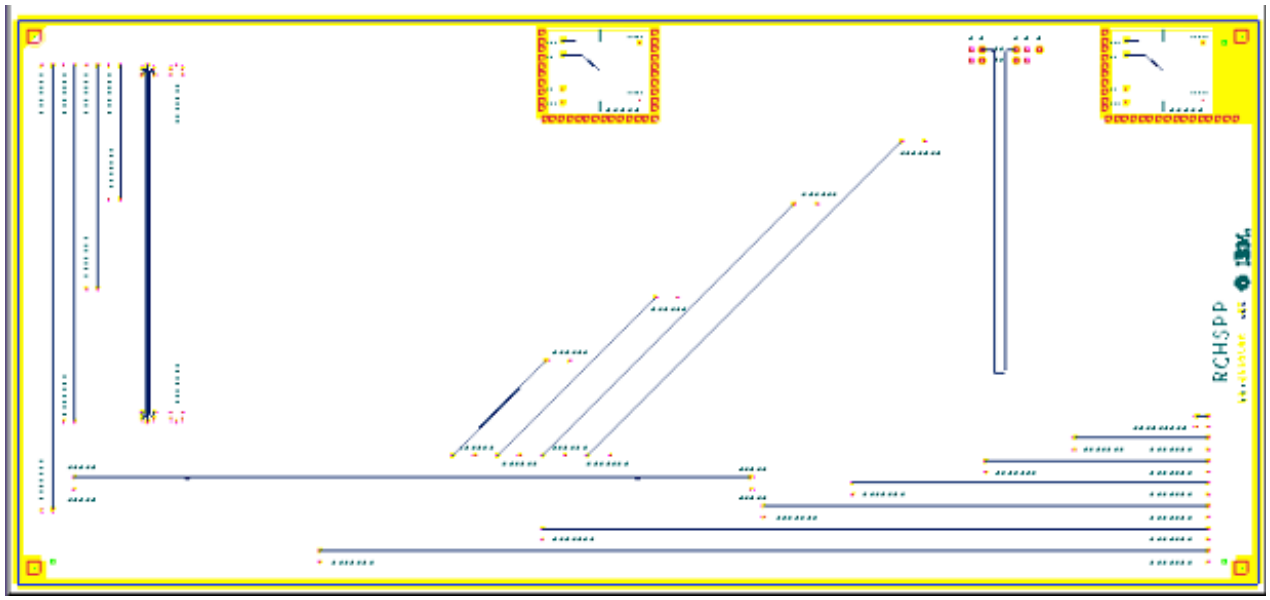
BACKUP

Short Pulse Propagation

- **Short Pulse Propagation Technique**
  - **Provides Time Domain Broadband Assessment of Laminate Material Dielectric Constant and Loss Tangent**
  - **Capable of Providing Results Up to 50GHz With Proper Equipment.**
    - **Setup Used for iNEMI HF Effort Will Provide Valid Results Up To 20GHz**
  - **Uses Test Structures Which Are Used in Real Applications.**
  - **Material is Excited in Same Fashion as System Operation vs. Traditional Resonant Techniques**

SPP Test Vehicle Design





Cross Section Definition is Flexible. Desire One Resin Rich and One Resin Poor Building Block

Example Results, Halogen Free Laminate

- **Example Results, Polyclad HF571 (now Isola)**
  - **November, 2005**

Part 5 - S3 (71% resin)		
Freq, GHz	Df	Dk
1.00E-04	0.0107	4.663
2.15E-04	0.0115	4.633
4.64E-04	0.0122	4.607
1.00E-03	0.0130	4.578
2.15E-03	0.0138	4.548
4.64E-03	0.0145	4.517
1.00E-02	0.0153	4.484
2.15E-02	0.0161	4.450
4.64E-02	0.0168	4.414
1.00E-01	0.0176	4.377
2.15E-01	0.0184	4.339
4.64E-01	0.0191	4.299
5.00E-01	0.0192	4.295
7.33E-01	0.0196	4.275
1.00E+00	0.0199	4.258
1.50E+00	0.0203	4.236
2.00E+00	0.0206	4.220
2.50E+00	0.0208	4.208
3.00E+00	0.0210	4.198
5.00E+00	0.0219	4.170
6.00E+00	0.0222	4.159
8.00E+00	0.0227	4.141
1.00E+01	0.0230	4.127
1.20E+01	0.0231	4.115
1.50E+01	0.0231	4.101
1.80E+01	0.0231	4.090
2.00E+01	0.0231	4.083

Part 1 - S6 (56% resin)		
Freq, GHz	Df	Dk
1.00E-04	0.0090	4.688
2.15E-04	0.0098	4.663
4.64E-04	0.0106	4.640
1.00E-03	0.0113	4.615
2.15E-03	0.0121	4.589
4.64E-03	0.0129	4.560
1.00E-02	0.0137	4.531
2.15E-02	0.0145	4.500
4.64E-02	0.0153	4.467
1.00E-01	0.0160	4.433
2.15E-01	0.0168	4.398
4.64E-01	0.0176	4.361
5.00E-01	0.0177	4.357
7.33E-01	0.0181	4.338
1.00E+00	0.0184	4.323
1.50E+00	0.0188	4.302
2.00E+00	0.0191	4.287
2.50E+00	0.0193	4.276
3.00E+00	0.0196	4.266
5.00E+00	0.0203	4.239
6.00E+00	0.0206	4.229
8.00E+00	0.0211	4.212
1.00E+01	0.0214	4.199
1.20E+01	0.0216	4.189
1.50E+01	0.0218	4.175
1.80E+01	0.0219	4.164
2.00E+01	0.0220	4.158

MEB Test Vehicle Details

- **Flexible design**
  - 8 Layer Thickness variable from 0.031” to 0.150”
    - minimum 2.7mil cores, minimum 2 mil prepreg
  - 0.5, 1.0, 2.0 oz copper layers
  - Designed for 18”x24” panel (16.5x22.5” useable area)

- **Focus on material properties**
  - Reliability coupons
  - Electrical, Mechanical, Thermal property coupons
  - Minimal fabrication capability (trace/space coupons)

MEB Panel Layout

4 Quadrants – 4 Subpanels
2 each for electrical and mechanical focus

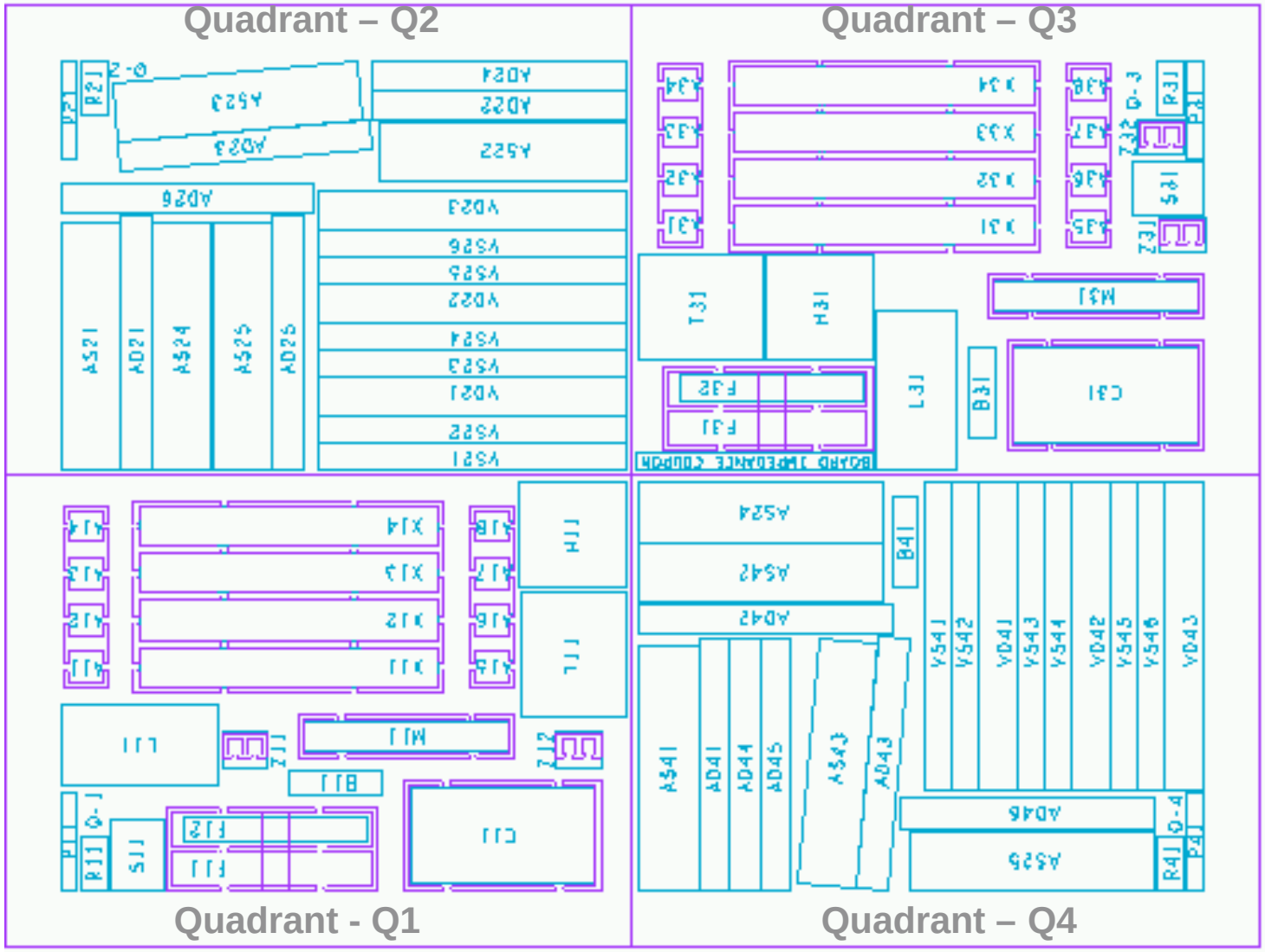
Electrical Tests Q2	**Mechanical Tests Q3**
Mechanical Tests Q1	**Electrical Tests Q4**

Registration in all 4 corners

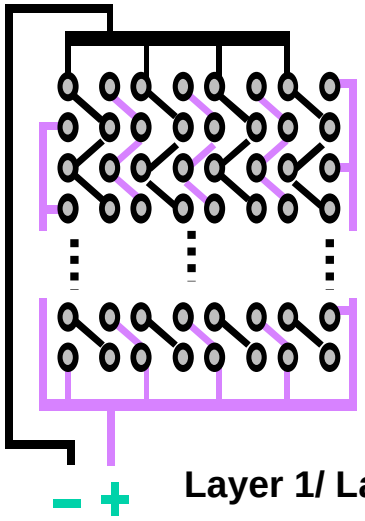
Coupon Designations

- **A – X-Section Coupon**
- **AD – Differential Impedance**
- **AS – Single Ended Impedance**
- **B – RF Coupon**
- **C – CAF Coupon**
- **F – Flex Modulus Coupon**
- **H – Hi Pot Coupon**
- **L – CAT Line and Space Coupon**
- **M – SIR/ MIR Coupon**
- **P – Perfect Test Coupon**
- **R – Outerlayer Registration Coupon**
- **S – Soldermask Registration Coupon**
- **T – Cu Peel Strength**
- **VD – VNA Differential Impedance**
- **VS – VNA Single Ended Impedance**
- **X – IST Coupons**
- **Z – TMA Coupons**

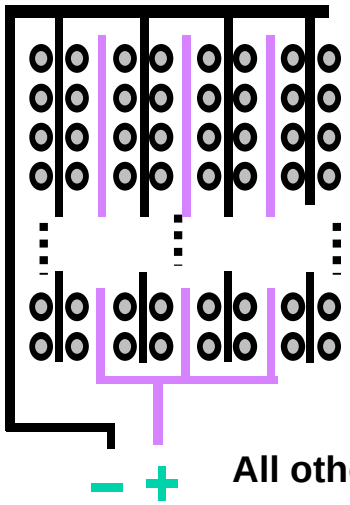
MEB Panel Layout



MEB CAF Coupon Design



Layer 1/ Layer 8



All other Layers

COUPON DESIGN

1) 12 mil drill on 32 mil grid (50 by 50 rows of holes = 2500 holes, approximately 1.6" square)
This is an approximate number of holes, can be changed slightly for best fit on test board.

Outerlayer and Innerlayer
PAD SIZE - .008" over drill
TRACE WIDTH - .004"
SPACING - .004" between trace and drilled hole
Connector traces to be .010"

2) 16 mil drill on 50 mil grid (30 by 30 rows of holes = 900 holes, approximately 1.5" square)
This is an approximate number of holes, can be changed slightly for best fit on test board.

Outerlayer and Innerlayer
PAD SIZE - .008" over drill
TRACE WIDTH - .018"
SPACING - .004" between trace and drilled hole
Connector traces to be .022"

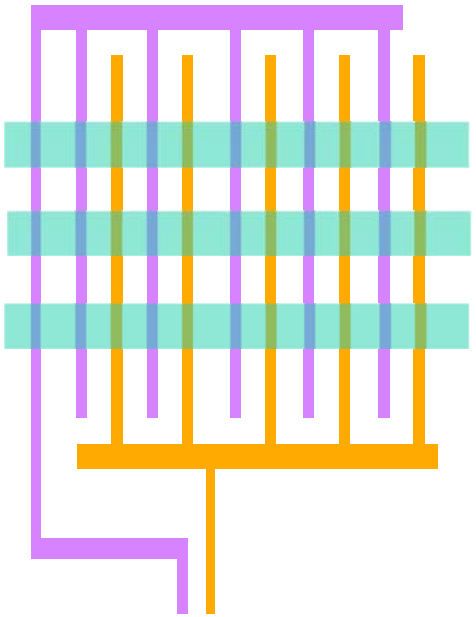
MEB SIR/MIR Coupon

Comb pattern

- 5mil traces/5mil spaces
- 3.5 inches long
- 25 teeth in each comb

Align all layers in z-axis

On outerlayers (1,n) place 20mil soldermask stripes on 50mil centers



Each Layer

MEB IST Coupons

4 Separate IST coupons per board

1) **Via/pad stack coupon**
   - 3 different via sizes and pad stacks on 40 mil grid
     - 10/20, 12/22, 14/26 = [Drill Bit Size] / Via Pad Size

2) **Drill grid coupon**
   - 3 different drill grids with same via/pad stack
     - .8 mm, 1.0 mm, 1.27 mm = Drill Grids, 10/20 = [Drill Bit Size] / Via Pad Size

3) **Microvia and Buried via coupon**
   - 2 microvia sizes and 1 buried via size on 40 mil grid
     - 4 and 6 mil microvias in 10 mil pads, 10 mil buried via in 20 mil pad

4) **Large hole interconnect coupon**
   - 35 mil drill on 50 mil offset grid

So Why do this?

1. **Emerging consideration of "Progressive" public, institutional, and corporate procurement groups in Sweden, Norway, Denmark, Netherlands, Germany, UK, France, Japan. Companies without HF product offerings have begun to lose bids in these regions, esp. in the mobile phone space**

2. **Very limited CE and IT product offerings are available.**

3. **Political and NGO hot-button. NGOs like Greenpeace are targeting actions against companies that use TBBPA**

4. **Lack of legislation results in "material-of-the month" behavior driven by multiple environmental groups – need a coordinated effort driven by a major industry influence**

5. **Supply chain capability and capacity is not established. Standards and generic technology.**

What is Halogen Free?

1. JPCA (Japan Printed Circuit Association) JPCA-ES-01-1999 defines criteria and method for "halogen-free"
   - Br < 0.09wt% (900ppm)
   - Cl < 0.09wt% (900ppm)
2. IEC (International Electrotechnical Commission)
   - Finalized requirements of IEC 61249-2-21:
     - 900 ppm maximum Cl
     - 900 ppm maximum Br
     - 1500 ppm maximum total halogens
3. IPC - 4101B has adopted the IEC definition of halogen-free
   - 900 ppm maximum Cl
   - 900 ppm maximum Br
   - 1500 ppm maximum total halogens

Note: fluorine, iodine, and astatine (other Group VIIA halogens) are not restricted in the industry definition of "halogen-free".

TBBPA

- **In epoxy resin circuit boards, TBBA covalently reacts with the epoxy resin backbone and ceases to exist as a chemical entity.** ~96% of printed wiring boards utilize TBBA**.**
- **Swedish Environmental Protection Agency studies indicate that TBBA does not bind to human transthyretin in vivo,** suggesting no adverse endocrine effects**.**
- **In 1995, the World Health Organization (WHO IPCS) undertook a full scientific assessment of the environmental and human health impacts of TBBPA. Key findings from this study indicated that**
  - **1) TBBPA has little potential for bioaccumulation,**
  - **2) environmental detection is limited to very few sediment/soil samples and**
  - **3) the human health risks associated with TBBPA for the general population is considered to be insignificant.**
- **Six independent studies between 1990-1997 concluded that** TBBA is not found to be a significant source of potential human dioxin exposure upon proper incineration **(IPC, 2003)**
- **TBBPA has been analyzed for the presence of 15 2,3,7,8-substituted polybrominated-p-dibenzodioxins and dibenzofurans. None of the analytes were present at or above the quantitation limits established by the U.S. Environmental Protection Agency.**
- **TBBA has a 50 day half-life in aerobic and anaerobic solids (soil) and has an average half-life of 31 days in water.**

- **Proposed Test Strategy**
  - **Screening of Materials**
    - The third party lab evaluates these boards per IPC 6012B Class 2. This evaluation includes the following material related requirements:

      – 1X and 6X Thermal stress
      – -Glass Fiber protrusion
      – -Wicking
      – -plating integrity
      – -Etchback and Desmear

      – Thermal Shock
      – -Plating integrity
      – -Barrel separation
      – -Lifted lands
      – -Laminate Voids
      – -Laminate Cracks

      – Bow and Twist (PWB construction/material interaction)

      – Stack up analysis (validate prepreg yield per ply compares to Fab stackup)

      – Thermal Analysis (Tg and Delta Tg)

      – Soldermask thickness (Halogen Free board requires halogen free soldermask: validate thickness requirements to IPC SM 840