Unique Implementation of a 15 Layer, Unboned/Looseleaf, Bookbinder Rigid Flex with Backdrill and LGA Interconnect

John Dangler, IBM
Rochester, Minnesota
Jeffrey Taylor, Lenovo
Research Triangle Park, North Carolina
Cynnthia A. Verbrugge, Amphenol
Minneapolis, Minnesota

Abstract

While flex and rigid flex (IPC-6013 Types 1 through 4[i][1]) have always been important in 3D packaging to help resolve space constraints and meet other design requirements, the continued push for denser packaging and higher performance has only increased the demand for more complex interconnects. Often we forget that a flex is more than a mechanical solution but that it is a critical part in controlling signal integrity and meeting other electrical performance requirements. Any design must be manufacturable, reliable and meet cost constraints.

We will be examining a packaging solution for a server application that met all requirements thru a combination of key design points including:

- -Rigid Flex (IPC-6013 type 4)
- -15 layer cross section
- -Unbonded/looseleaf construction
- -Bookbinder construction
- -Backdrill
- -LGA (Land Grid Array) interconnect

Cost, manufacturability, reliability, signal integrity, thermal and mechanical requirements were all considered during development. The collaborative efforts of mechanical development, signal integrity modeling and input, qualification engineering, production engineering, cost engineering, sourcing team support and manufacturability and cost feedback from the fabricator were key to creating a final design that was an optimum balance considering various trade-offs.

More than a simple stack of circuit materials, the unbonded/looseleaf, bookbinder cross section and LGA interconnect was able to meet the tight rigid flex mechanical bend radius requirements and the small interconnect footprint requirements. The flexibility of the rigid flex met the system mechanical requirements related to tolerances between the two mating LGA interconnect areas. Critical signal integrity requirements were met thru the selected cross section, backdrill and the utilizing an LGA interconnect solution.

This paper includes details as to how we went from concept to initial development, to design iterations and prototyping, thru qualification into a final product in volume production.

While this product may look very much like a technology test vehicle, it successfully and elegantly solved a real world challenge.

Introduction

In developing any server, especially high density, scalable, high performance blade servers, significant electronic packaging challenges are encountered. High speed, dense interconnect between blades is often required to achieve desired system performance.

In the application described in this paper challenging space, signal integrity, cost, scalabilty and usability requirements were defined for signal interconnect between blades. An interconnect solution using rigid flex cables, LGA interconnect and scalabilty cards was proposed.

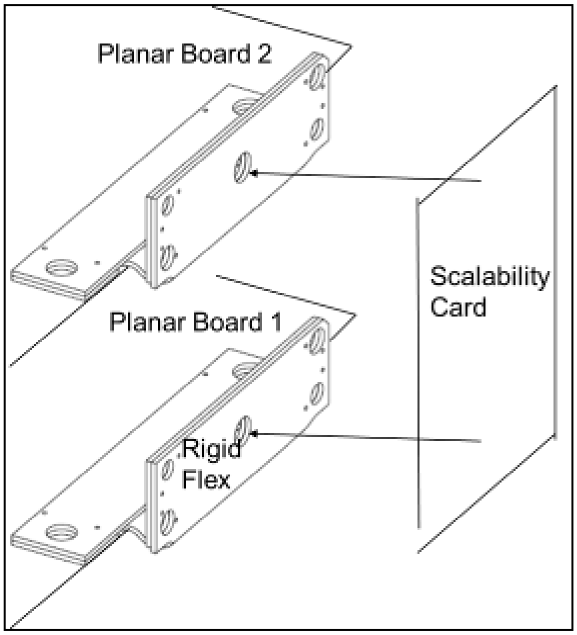


Figure 1 - Original Interconnect Concept

Construction
While flex may be ideally suited for applications requiring interconnects within a tight form-factor, not all flex constructions are up to the job of delivering high density interconnects when space is at a premium. This application required we bend 13 conductive layers 90 degrees within a span of 15.25mm. Adding to the difficulties associated with such a severe bend was the impedance requirements on the 5 signal layers. Impedance control and good signal integrity properties depend on thick inner-layer dielectrics resulting in a significantly thicker flex than standard non-impedance controlled circuit.

Why Type 4 (Rigid-flex)
Special considerations are required when building high layer-count FPCs (Flexible Printed Circuits). A standard construction multi-layer (IPC-6013 type 3) is adequate for most applications; however as layer count rises, or more importantly circuit thickness increases special attention must be paid to the materials used within the stack. Of primary importance is CTE (Coefficient of Thermal Expansion) match between all materials within the stack. As seen in the Figure 2, a large portion of the stack-up is comprised of acrylic adhesive from the bond plys.

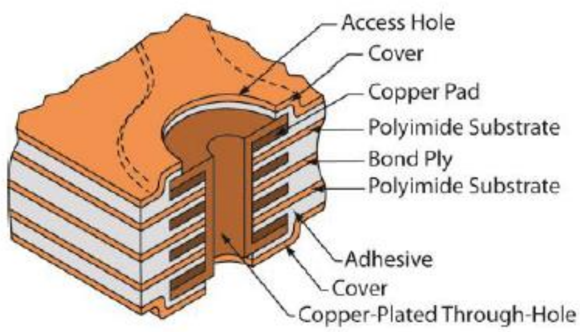


Figure 2 – Typical Type-3 Construction

In Figure 3, we can see the materials that make up the typical IPC type 4 multilayer. Successive layers of dielectric, adhesive, and conductive layers make up the flex. When it comes to PTHs (Plated Through Holes) the expansion of the materials in the z-axis with temperature rise becomes a real concern. As the material 'swells' in the z-axis it creates strain on the plated barrel, enough strain and the barrel cracks resulting in an electrical open. It is important the CTE match as closely as possible. The most common flex materials have a pretty good CTE match in the 'x' or 'planner' direction, but not so for the 'z'.

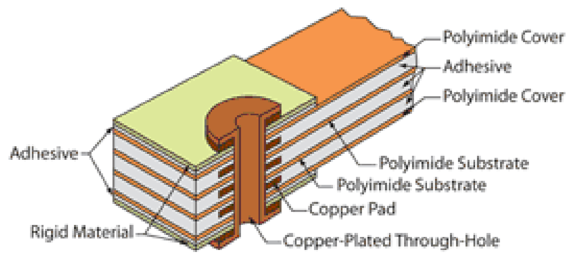


Figure 3 – Typical Type 4 Rigid Flex Construction

Table 1 – Common CTE Values for Flex Materials (z-axis)

FR4 (Rigid Material)	50-70 ppm/°C
Polyimide	100-105 ppm/°C
Acrylic Adhesive	100 ppm/°C (400 ppm/°C >Tg)
Note: Acrylic Tg 40°C	

As we can see in Table 1, once we rise above the Tg (Glass Transition Temperature) of Acrylic adhesive at 40C our z-expansion rises to 4x the rate of the other materials in our stack. This is the critical reason we moved to a rigid flex Type 4 construction with cut back coverlay and acrylic bonding films. These layers were stopped in the flex/rigid transition zone. This eliminated acrylic adhesive in the via area. The cutback coverlay and acrylic bonding films can be seen in Figures 7 and 8.

A note on the Tg value regarding acrylic adhesive. There can be concern on the part of designers when they see a Tg value of 40C. This is really of no concern as long as proper design considerations are followed in our stack-up. Acrylic adhesive is uniquely qualified for use in FPCs. Its properties are both thermo-set and thermoplastic. It is exactly these properties that allow the multiple lamination cycles required when building up a multi-layer with several sub-composites. FPCs of this construction are often rated for a MOT (Maximum Operating Temperature) of 105C. Many flexes of this construction are operating at elevated MOTs of 150C for extended time with no detrimental effect.

Bend Radius Considerations

IPC-6013 recommendations state that a flex circuit should have a minimum bend radius of 10 times its thickness. As far as "guidelines" go, this one is pretty safe however it fails to account for initial part thickness or material type. A very thin flex can go significantly tighter, even folding over on itself whereas a thicker circuit may require a more relaxed bend. In our application we had to bend a very thick circuit of 0.965mm (0.038 in) if we did not use an unbonded/looseleaf design. Our calculated minimum allowed radius per IPC-6013 would have been 9.65mm (.38 in). In real life situations radii are not perfect and we often require a bit more flex length for a comfortable installation. We had an un-bonded flex section length of 15.25mm to form our flex to 90 degrees. Our 'real world' finished radius requirement was determined to be 2.54mm (.1 in) for best fit. This makes our planned design 3.8 times tighter than allowed by industry design standards without unbonded/looseleaf/bookbinder.

In a typical instance where we must go below the minimum recommended bend radius we would incorporate a 'loose-leaf' approach. Individual layers would be separated within the flex stack-up (see Fig 5). By separating the layers into multiple sub composites within the stack-up, we can recalculate our minimum bend radius based on the thickness of the individual layer. This can be quite effective; however in our situation we still had a flex region of only 15.25mm. Even unbounded layers would not allow for enough give within the stack to allow for a stress free bend.

The Bookbinder

By making each of our unbounded sub-composites slightly longer than the one below it, we can allow room for our sub-composite to bend without applying undue stress to itself or the layer immediately adjacent to it. Each sub-composite length is calculated to allow the sub-composite to rest under it without interference.

Table 2 Progressive Lengths of Sub-composites

Progressive layer lengths	
Flexible layers	**Overall width (mm)**
2, 3, 4, 5	**47.46**
6, 7, 8	**46.69**
9, 10, 11	**45.92**
12, 13, 14	**45.16**

By virtue of our thickest sub-composite now being .3mm (0.012 in) we can re-calculate our minimum bend radius based on this new value. We now have a recommended minimum bend radius of 3.0mm (.12 in), 1/3 of our original design minimum!

Stress applied in flex zone during form

Using the materials above the stress-forces on the book-binder portion of our Rigid-Flex was calculated.
Plane strain allowed for a 2D cross-section. Contact between sub-composites was modeled allowing the effect of sub-composites coming into contact with each other could be observed. As there are no direct modeling parameters for flex materials assumptions had to be made. The flex layers were all assigned the same modulus with the rigid sections being treated as steel.

As seen in figure 11 the reactive force between the two ends of the rigid flex was analyzed.

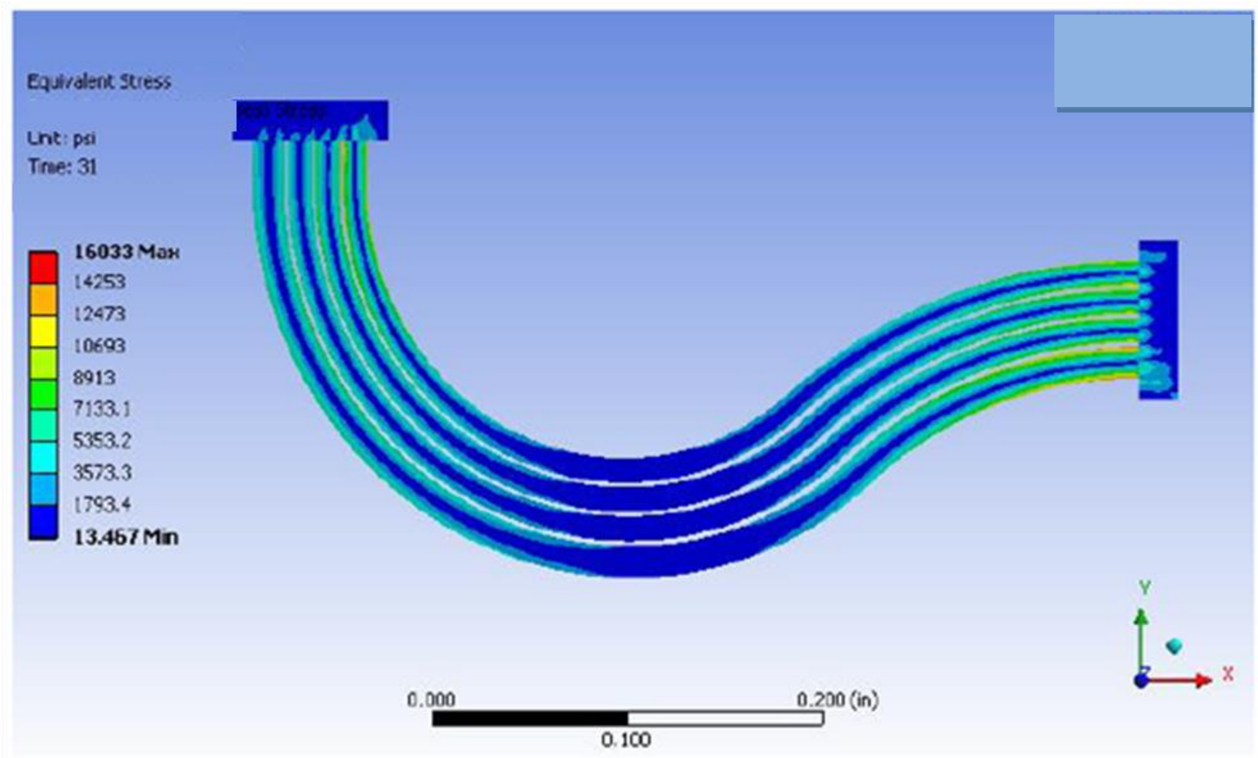


Figure 4 – Sub-composite Stress Model

Final Rigid Flex Stack-up and Microsections

Figure 5 shows the final stack-up. Figure 6 shows the construction without cut back coverlay/acrylic bonding film which would have put 8 mils of acrylic adhesive in the via area which is not preferred per previous discussion and was not used. Figure 7 and 8 show microsections of the final product. Figure 9 shows a microsection of vias in the rigid area.

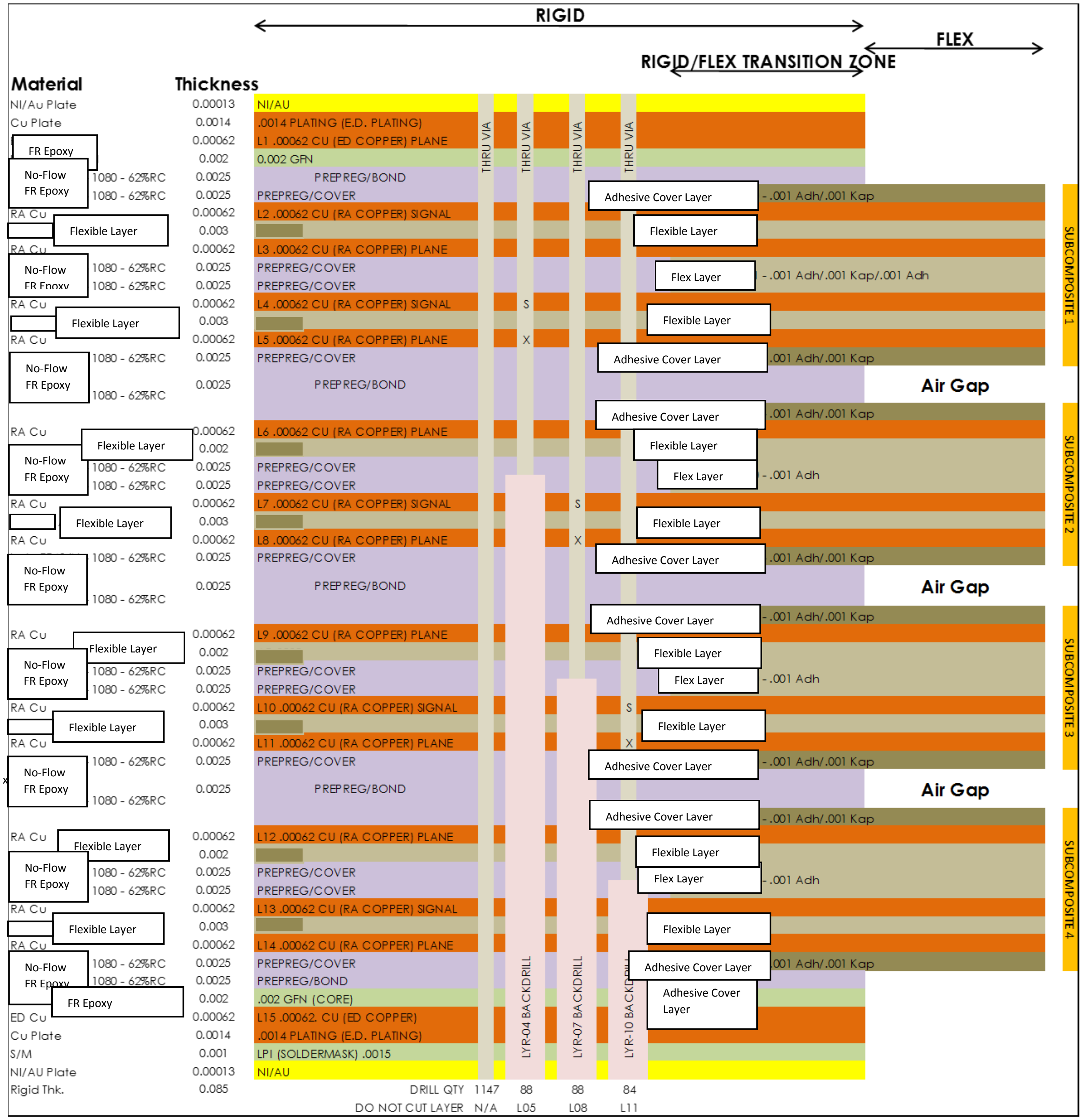


Figure 5 – Final Bookbinder Rigid Flex Stack-up

Figure 6 – Alternate Stack-up Without Cut Back Coverlay/Acrylic Bonding Film (not used)

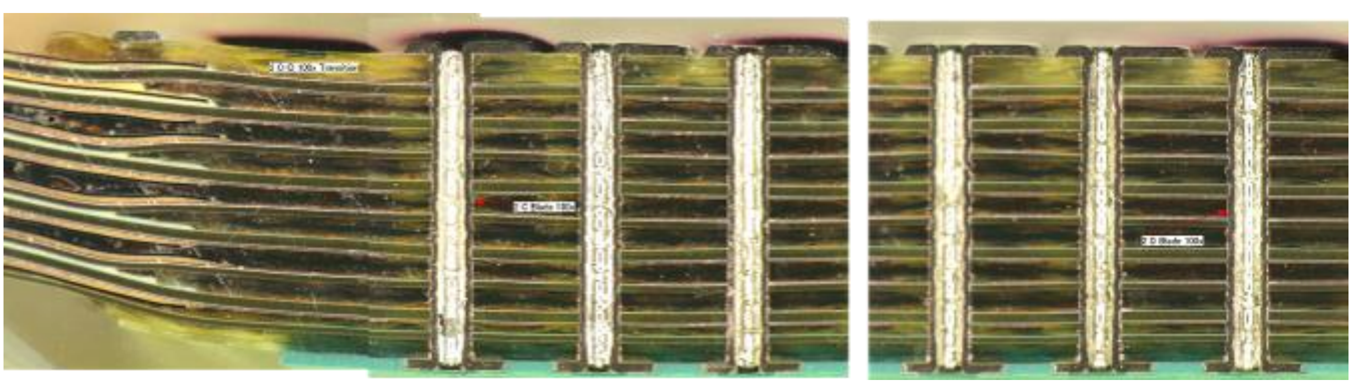


Figure 7 – Microsection of Flex/Rigid Transition Zone and Rigid Section (with Vias)

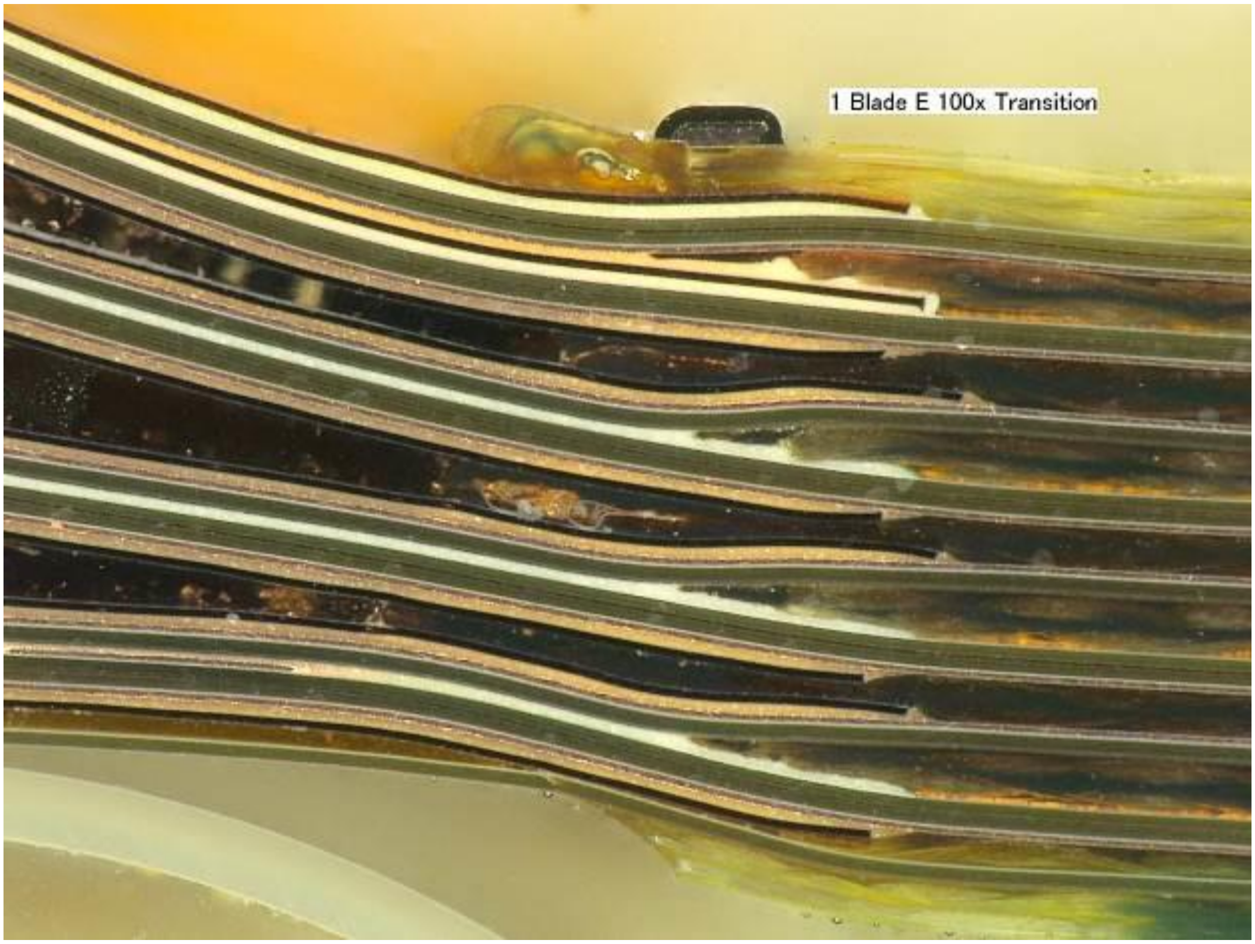


Figure 8 – Microsection of Flex/Rigid Transition Zone

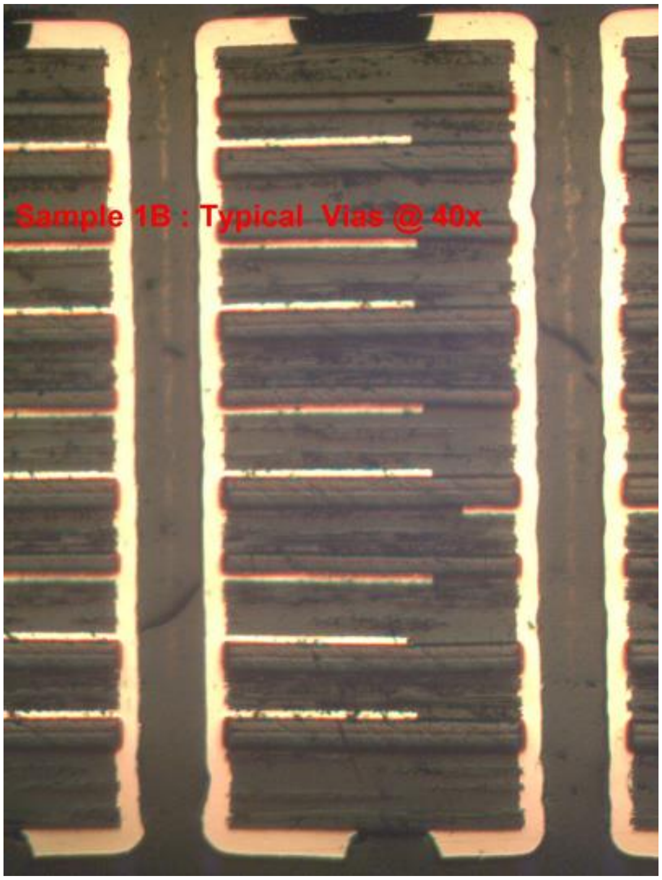


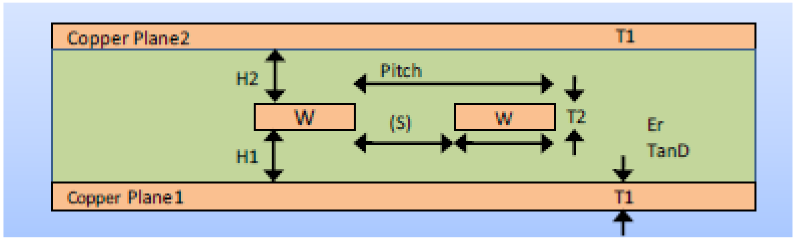
Figure 9 – Microsection of Vias

Impedance Considerations, Calculations

Adding to the complexity of this design is the requirement for multiple impedances both stripline and microstrip. Critical signals were kept off the microstrip layer (layer 2).

Stripline Modeling

Stripline modeling was straight forward. With our signal layers lying completely between the return planes there is no impact on impedance values due to proximity of adjacent layers. Calculations are straight forward and the resulting values are consistent between unbounded layers in the flex. Loss per inch @ 3.2 Ghz are recorded for each line width.



Var	Desc.
W	Trace Width
Pitch	In pair pitch
(S)	In pair airgap (Pitch - W)
T1	Copper Plane Thickness
T2	Signal conductor thickness
H1	Dielectric thickness below signal conductor
H2	Dielectric thickness above signal conductor
Er	Dielectric constant
TanD	Dielectric loss tangent

Figure 10 – Impedance Calculation Parameters

RUN#	W	Pitch	(S)	T1	T2	H1	H2	Er	TanD	Zd	Loss dB/in @3.2Ghz	Notes	Reaction Force (lb) (see pg 11-21 for details)	
Stripline - 0.5 oz copper, 3 mil cores						Nominal Design Point							up/down	Left/Right
1	3.2	9.8	6.6	0.65	0.65	3	3	3.3	0.01	92.7	0.43	min trace width	12.5	92.5
2	3.8	9.8	6							84.6	0.42	nominal trace width		
3	4.4	9.8	5.4							76.6	0.41	max trace width		
Stripline - 0.25 oz copper, 3 mil cores														
4	3.5	9.8	6.3	0.33	0.33	3	3	3.3	0.01	93.5	0.46	min trace width	5.6	41.5
5	4.2	9.8	5.6							84.0	0.44	nominal trace width		
6	4.8	9.8	5							77.2	0.44	max trace width		
Stripline - 0.25 oz copper, 2 & 3 mil cores														
7	2.8	9.8	7	0.33	0.33	2	3	3.3	0.01	93.1	0.53	min trace width	4.1	30.3
8	3.3	9.8	6.5							85.0	0.52	nominal trace width		
9	3.9	9.8	5.9							76.9	0.50	max trace width		
Stripline - 0.25 oz copper, 2 mil cores														
10	2.3	9.8	7.5	0.33	0.33	2	2	3.3	0.01	93.5	0.59	min trace width	2.8	20.8
11	2.8	9.8	7							84.0	0.58	nominal trace width		
12	3.2	9.8	6.6							77.8	0.56	max trace width		
Stripline - 0.5 oz copper, 3.4/2.0 mil core,												Nominal design point		
19	3.5	9.8	9.8	0.65	0.65	3.4	2.1	2.6/2.45	0.001	93.3	0.29	min trace width	13.3	98.1
20	4.1	9.8	9.8							85.2	0.29	nominal trace width		
21	4.8	9.8	5.1							77.1	0.30	max trace width		

Figure 11 – Impedance Modeling Results

Part size, panelization and costs

The rectangular shape of the product and 78mm x 45mm overall size allowed for good panelizations even with panelization considerations for the bookbinder manufacturing processes. Initial production was done 28 up on a 457 mm x 610 (18 in x 24 in) panel. Production was moved to 60 up on a 610 mm x 914 mm (24 in x 36 in) panel to reduce costs. A second low cost geography manufacturing site was qualified using a 229 mm x 305mm (9 in x 12 in) panel size.

General Development and Qualification Activities

During product development backdrill was added to the product requirements to improve signal integrity margin. The backdrill requirement was added to vias with the three longest stub lengths covering 260 vias. The vias with the shortest stubs did not require backdrill. Figure 12 shows a 3D x-ray image of the product with backdrill. Figure 13 shows microsection mounts of the three backdrill depths.

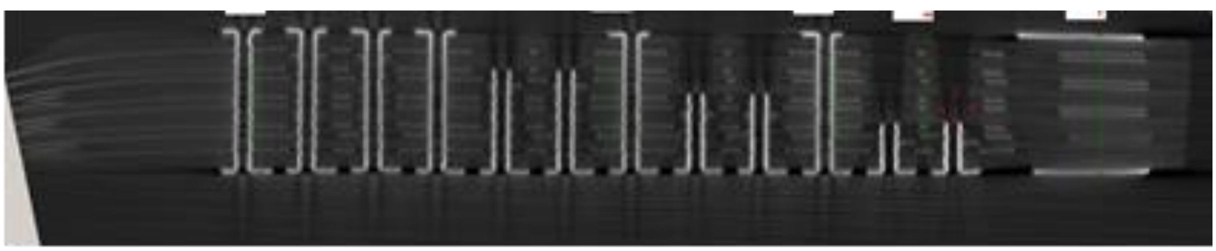


Figure 12 - 3D X-ray Image of Rigid Flex Section Including Backdrill

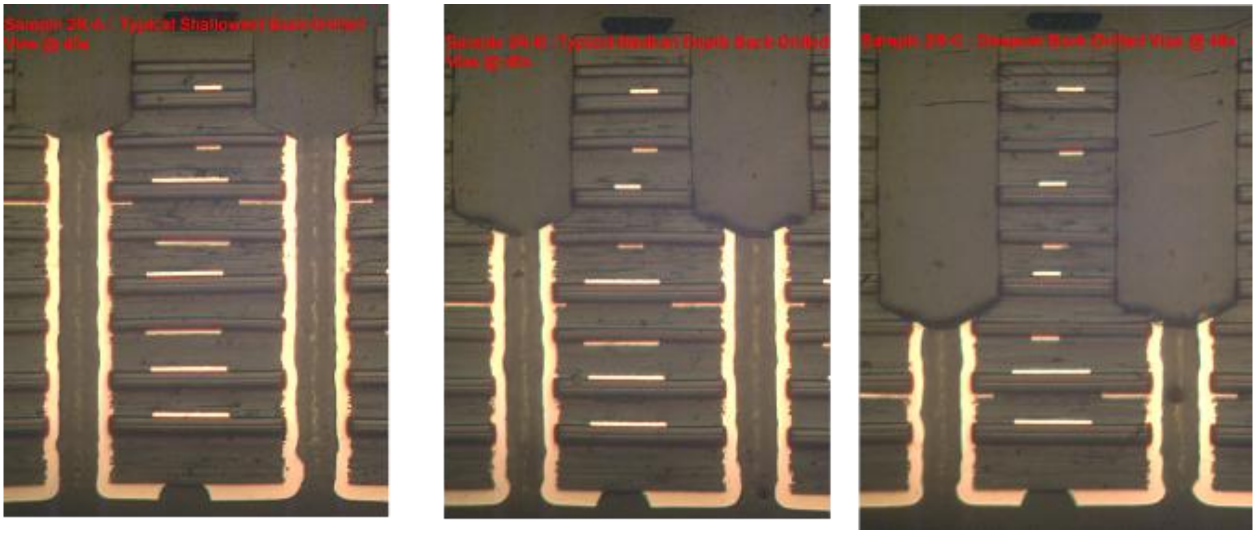


Figure 13: Microsection of 3 Backdrill Depths

Via hole copper plating minimum average requirements for through holes is higher in flexible printed boards than in rigid boards. Type 3 and 4 flexible printed boards have a 25 um (984 uin) minimum average requirement per IPC-6013C. Rigid boards class 2 have a 20 um (787 uin) minimum average per IPC-6012[ii][2].

Qualification tests included Accelerated Thermal Cycling testing of backdrilled coupons. No fails were seen thru 600 cycles from -40C to +90C.

The LGA interconnect for this application uses gold over nickel to gold over nickel interconnect metallurgy. For high reliability minimum gold thicknesses on the rigid flex interconnect pads was specified as 0.00076 mm (0.000030 in). Minimum nickel thicknesses was specified as 0.00127 mm (0.000050 in). Porosity testing, gold and nickel harnesses testing, FTIR analysis, and ESCA analysis were performed on the interconnect surfaces during qualification.

Additional data collected during qualification included:

-First article inspection reports from the fabricator

-Itemized confirmation of compliance to all print notes

-Verification data for of all print dimensions/print notes

-Process capability data for key print requirements including impedance, plating thickness and critical mechanical dimensions.

-Delivery of microsection pictures, measured data and physical mounts

-Failure analysis of all early build fails to determine root cause

-Hi-Pot test data

The LGA interconnect allowed for a dense interconnect solution with good signal integrity properties. Mechanical hardware including bolster plates, alignment pins and screws were designed to provide proper alignment and normal force for the LGA contacts. Figure 27 shows several of these features. Use of the LGA interconnect eliminated thermal exposures to the raw rigid flex due to soldering. Figure 14 shows the via and pad structure for the LGA interconnect.

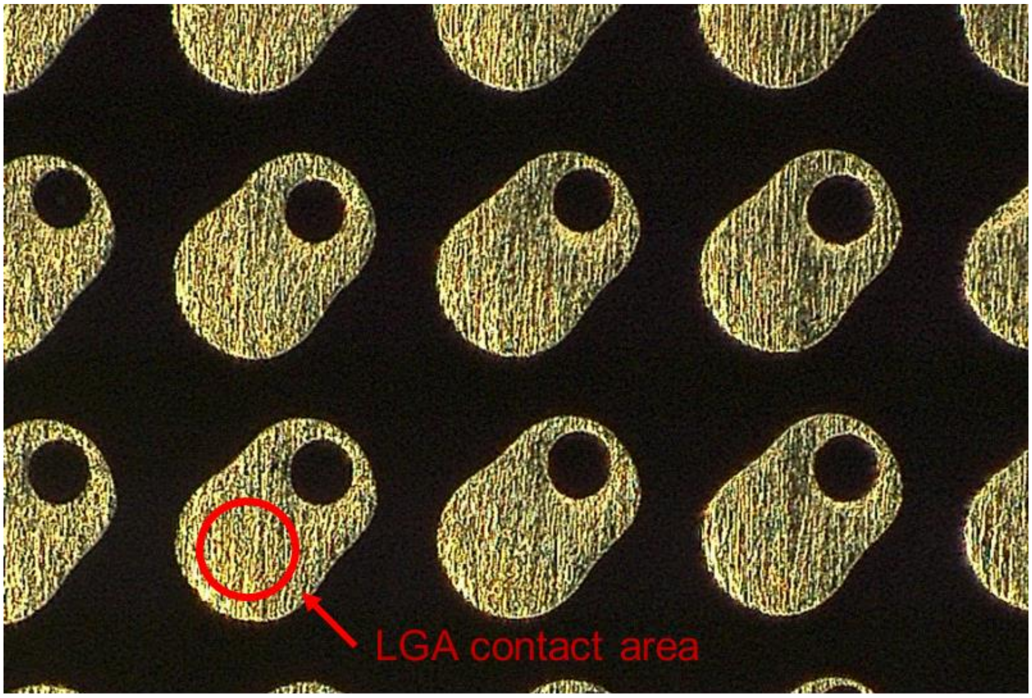


Figure 14 – Via and LGA Pad Structure

Conductive Anodic Filament testing and pre-preg rotation
Low or no flow pre-pregs are often required for rigid flex applications to control epoxy flow at the rigid flex to flex interface. With the 1mm LGA contact pitch and .39mm vias there was significant concern in early development to drive initial CAF coupon build in parallel with initial part builds and early testing.

Test methods and coupons were similar to Conductive Anodic Filament (CAF) Resistance Test: X-Y Axis defined in IPC-TM-650 Number 2.6.25[iii][3]. The coupon cross section replicated the rigid portion of the rigid flex. Fails occurred within the first 50 hours of testing. A significant numbers of fails occurred within the first 150 hours of testing on coupons built with both standard and spread glass pre-pregs.

A team consisting of the pre-preg supplier, the fabricator and the end user evaluated options which included additional glass types, better CAF performing materials, additional flow testing in conjunction with additional cutting back of pre-pregs and alternate lamination conditions. Based on available data from this and other programs and engineering judgement all options had significant risk due to short program schedules.

The team then considered pre-preg rotation.

With the LGA connector on both ends of this rigid flex and no additional vias on the part, the original design had all vias on a 1mm x 1mm grid. While this is unique compared to complex flex or boards with logic, it is fairly common for flex cables used in interconnect solutions. By rotating the pre-preg 26.6 degrees as shown in figure 15 the, via to via distance was increased from .75mm to 2.0mm. Pre-pregs were rotated instead of rotating parts to facilitate manufacturing the progressive bookbinder sub-composite lengths in multiple parts across a panel.

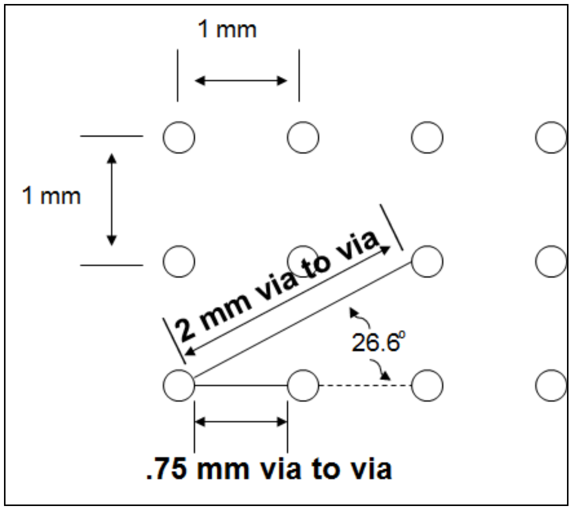


Figure 15 – Via to Via Distance with Rotated and Non-rotated Pre-pregs

Figures 16 and 17 shows a CAF coupon failures. Failure analysis of the original coupons verified electromigrated copper as the defect mode. The orthogonal view in Figure 18 shows voiding and electromigrated copper between and along individual glass fibers.

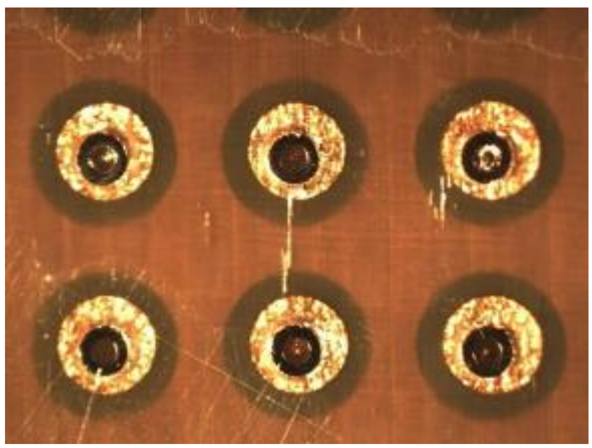


Figure 16 – CAF Coupon Fail Site

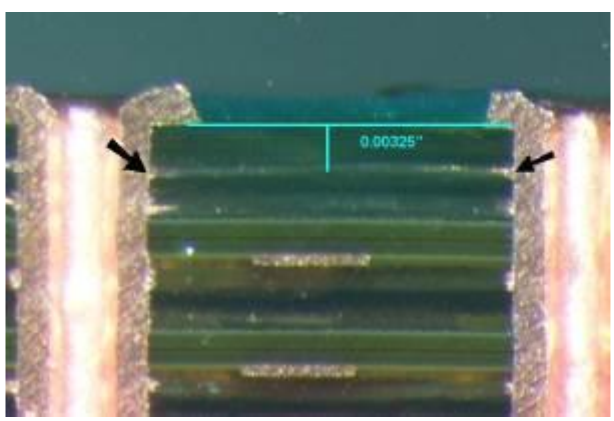


Figure 17 – Microsection of CAF Coupon Fail Site

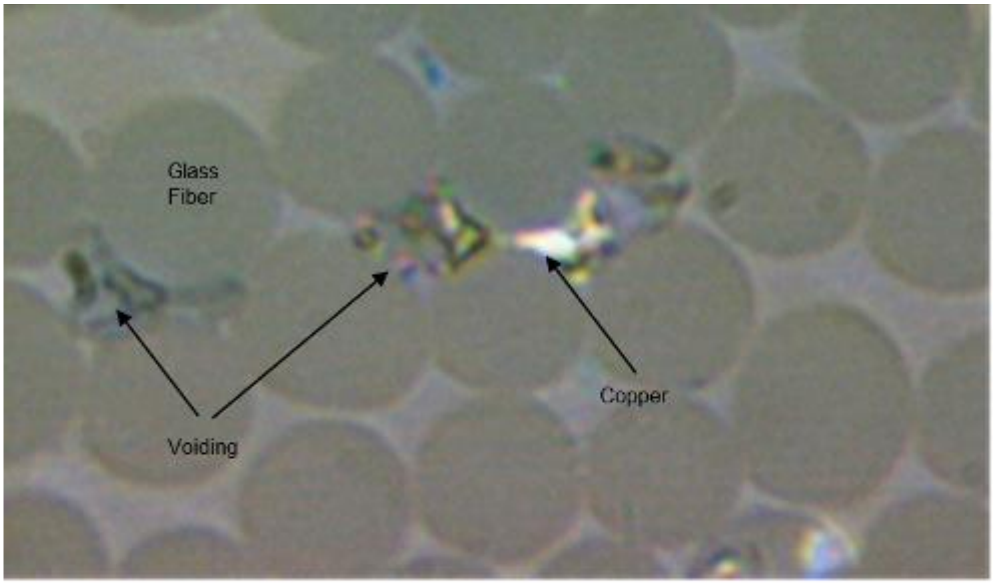


Figure 18 – Orthogonal Microsection of CAF Coupon Fail Site

Cross section of parts and coupons with rotated pre-preg confirmed the rotation was successful in the manufacturing environments as shown in figure 19. Figure 20 shows the rotation effect on pre-preg panelization

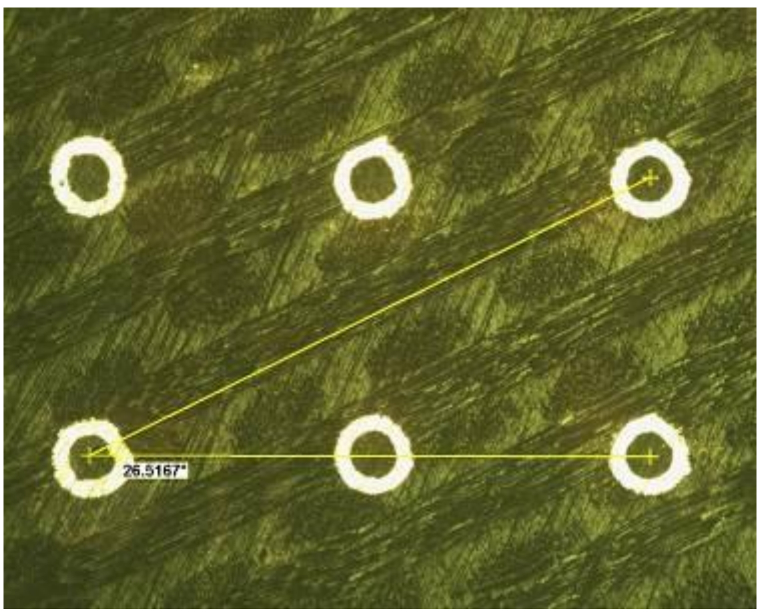


Figure 19 - Confirmation of Pre-preg Rotation

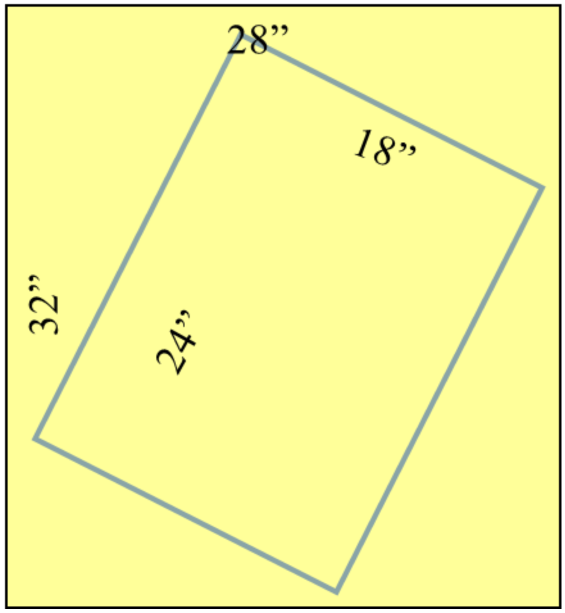


Figure 20: Pre-preg Panel Utilization with Rotation

A second build of coupons was built with and without pre-preg rotation. As seen in figure 21, the non-rotated coupons from pass 1 and 2 performed poorly and the coupons with rotated pre-preg had no fails through 350 hours. Additional CAF testing on samples with rotated pre-preg and backdrilled vias at the initial and low cost geography manufacturing site had no fails thru 500 hours.

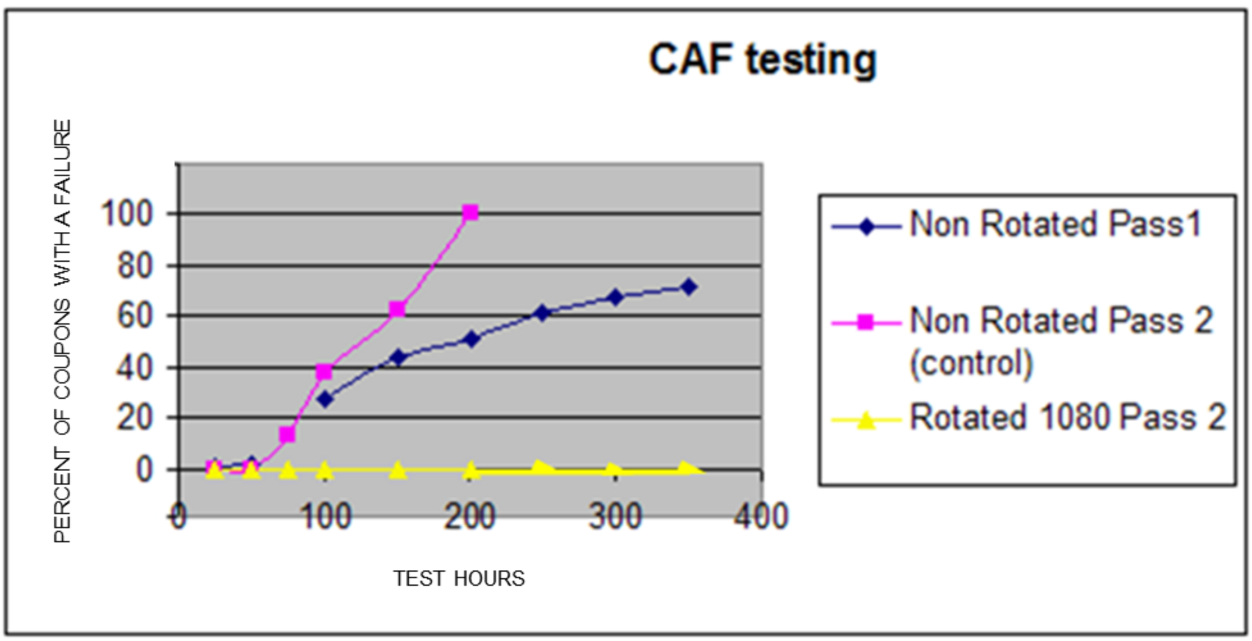


Figure 21 - CAF Testing Results

Final Implementation

Figures 22 and 23 show the final bookbinder rigid flex in flat form. The progressive lengths of the bookbinder can be seen. Figure 24 shows the product held in the 90 degree position-as it is positioned in the application. The alignment of the progressive lengths can be seen.

Figure 22 – Rigid Flex with LGA Contacts Shown

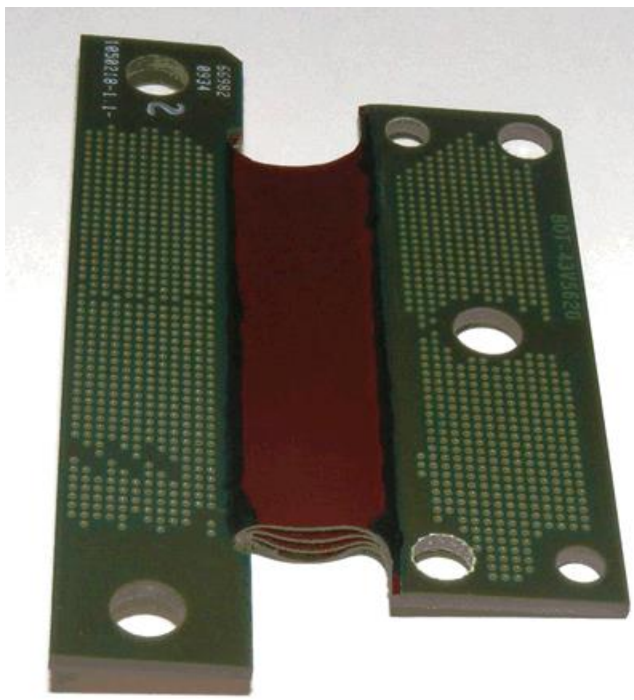


Figure 23 – Rigid Flex with Backside Shown

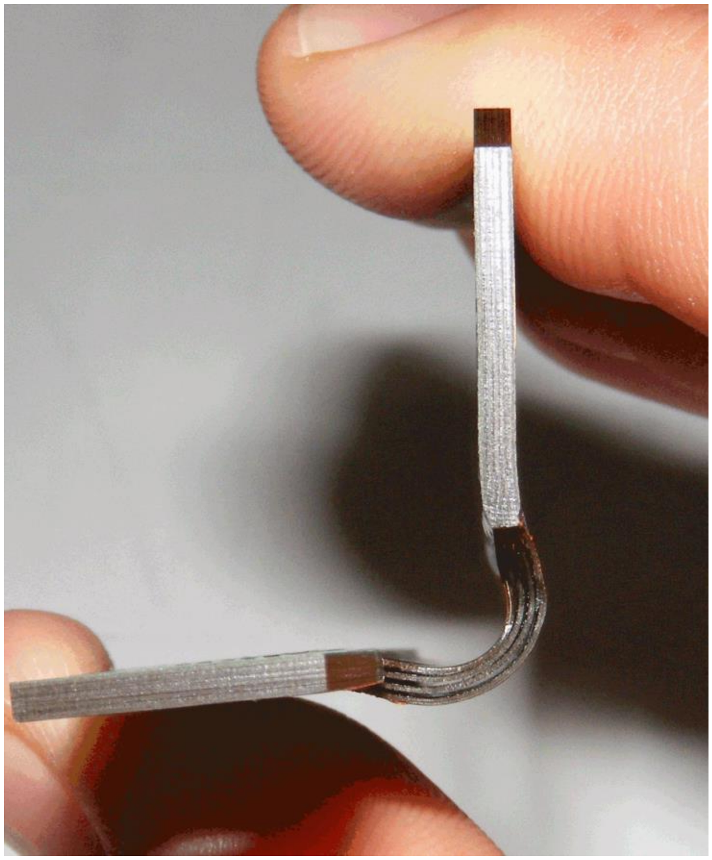


Figure 24 – Bookbinder Layers in Installed Position

Figure 25 – 2 Blade Server System

Figure 25 shows a 2 blade server system with the covers and the scalability card removed. Two rigid flex can be seen in the bottom right of the picture. Up to 4 blades could be connected.

Figure 26 shows a close up view of the interconnect area. The two rigid flex that can be seen have been electrically and mechanically attached to planar boards one and two with LGA contacts and mechanical hardware. The flex make 90 degree bends and can float on the two diagonal standoffs on each flex.

Figure 27 shows the LGA housing and LGA contacts on the scalability card. The two diagonal tapered pins provide alignment between scalability card/LGA housing/LGA contacts and each rigid flex.

Figure 28 shows the scalability card installed with the mechanical hardware completing the interconnect between the 2 planar boards.

Figure 26 – 2 Blade Server System Close-up

Figure 27 – 2 Blade Server System Scalability Card

Figure 29 – 2 Blade Server System with Scalability Card and Hardware Installed

Conclusions
This rigid flex design included several key elements, any of which on their own are a reason for special consideration. Together they were a significant challenge. By close collaboration between the flex supplier, material suppliers and end user we successfully implemented an elegant workable solution to a complex problem that addressed all requirements.

References

[1][i] Qualification and Performance Specification for Flexible Printed Boards, IPC-6013C, 2009

[2][ii] Qualification and Performance Specification for Rigid Printed Boards, IPC-6012D, 2010

[3][iii] IPC Test Methods Manual, IPC-TM-650, 2007

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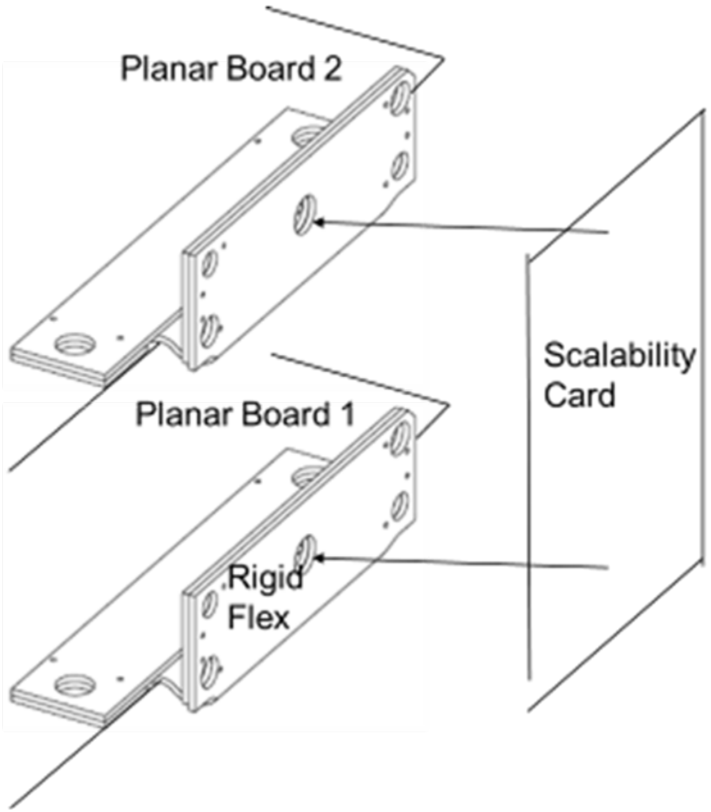
Original Concept/Requirements

- High speed blade to blade server system signal interconnect required
- Scalable up to 4 blades
- Mechanical space at a premium



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Bookbinder

- By making each of our unbounded sub-composites slightly longer than the one below it, we can allow room for our sub-composite to bend without applying undue stress to itself or the layer immediately adjacent to it. Each sub-composite length is calculated to allow the sub-composite to rest under it without interference.
- By virtue of our thickest sub-composite now being 0.012” (0.3mm) we can re-calculate our minimum bend radius based on this new value. We now have a recommended minimum bend radius of 0.12” (0.965mm), 1/3 of our original design minimum!

Bookbinder

Progressive layer lengths	
Flexible layers	**Overall width (mm)**
2, 3, 4, 5	**47.46**
6, 7, 8	**46.69**
9, 10, 11	**45.92**
12, 13, 14	**45.16**

Stress Applied in the Flex Zone

- Using the materials above the stress-forces on the book-binder portion of our Rigid-Flex was calculated;

Stress Applied in the Flex Zone

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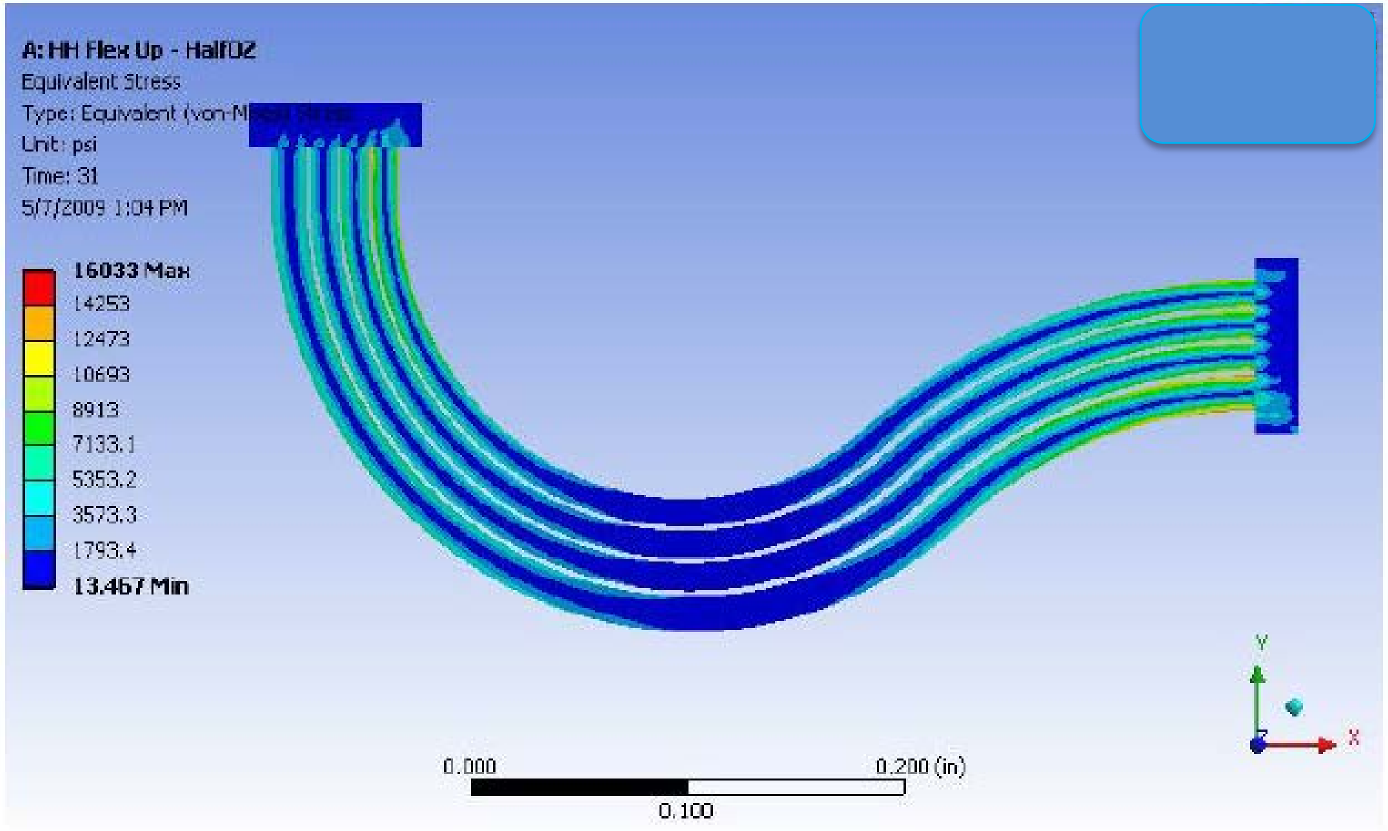
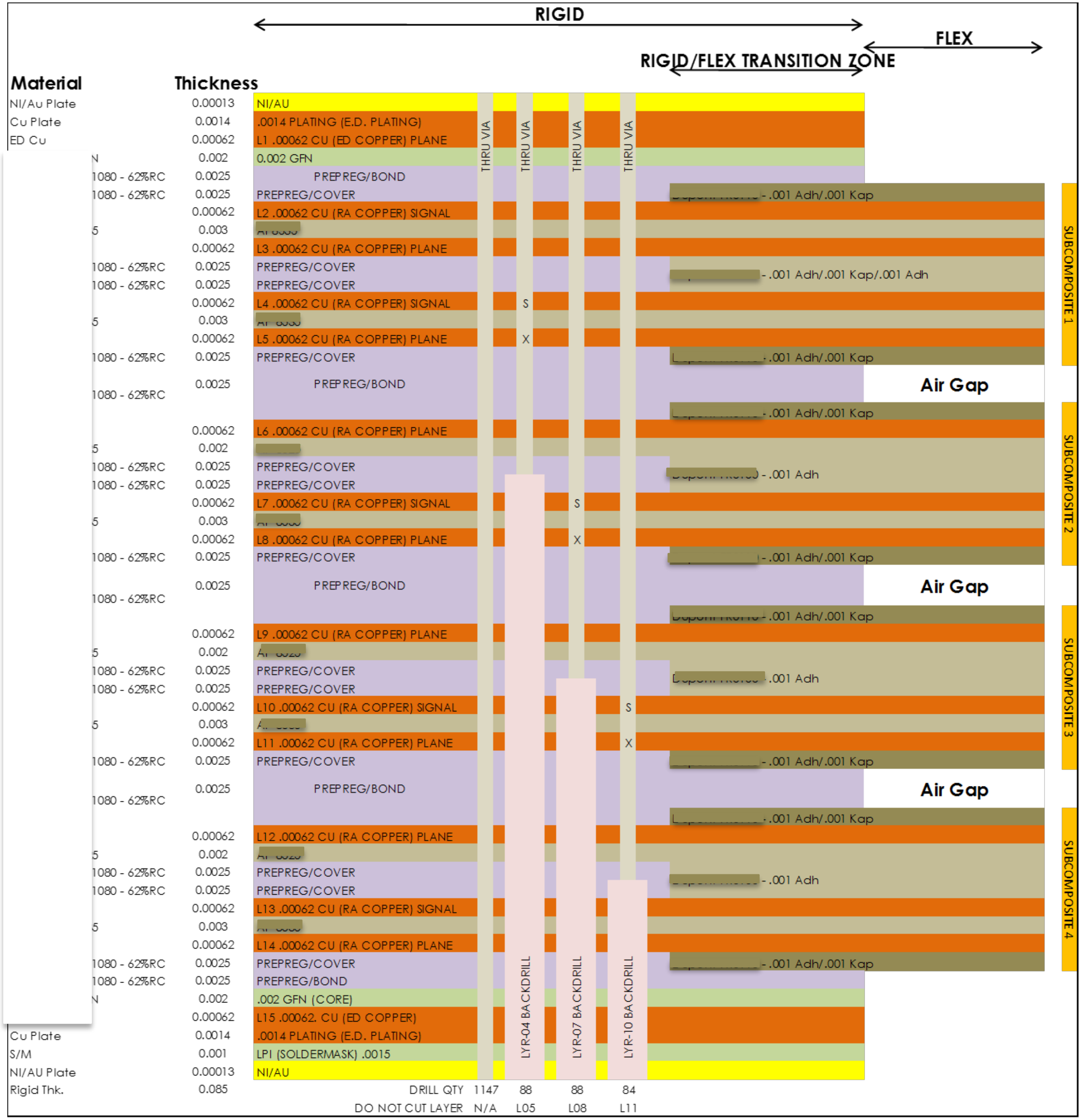
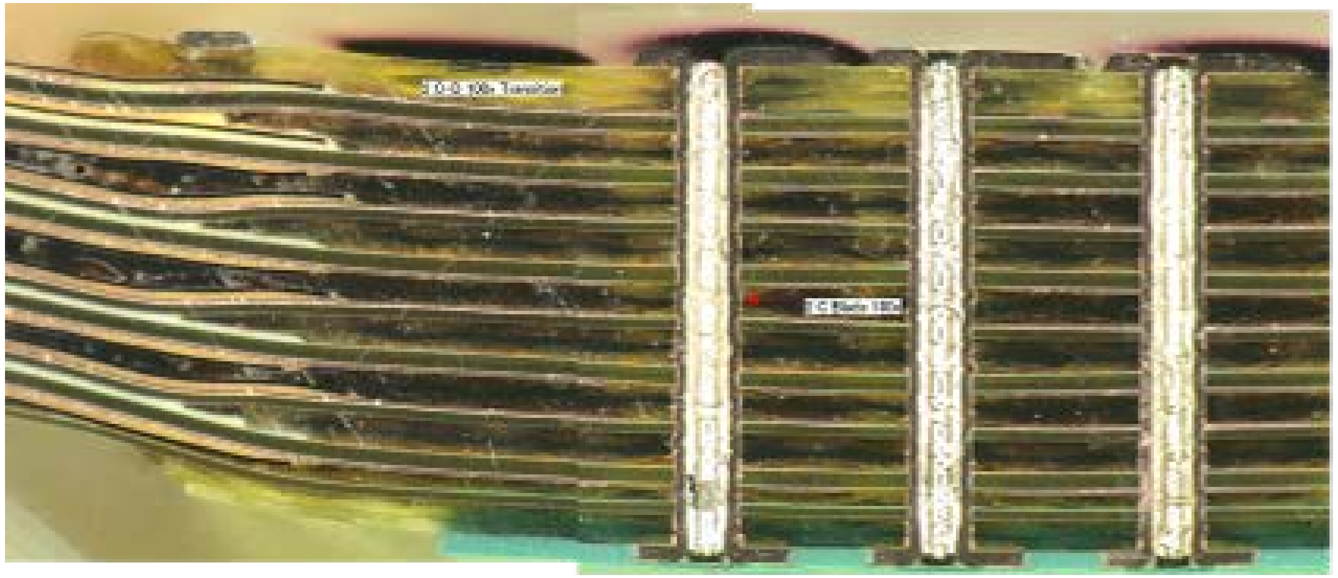


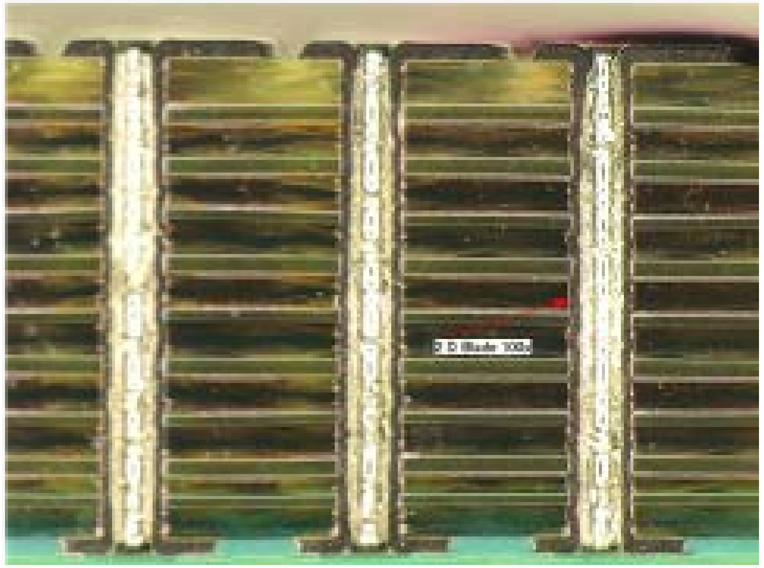
Stack-up



RIGID
FLEX
RIGID/FLEX TRANSITION ZONE
Material
Thickness
NI/Au Plate 0.00013 NI/AU
Cu Plate 0.0014 .0014 PLATING (E.D. PLATING)
ED Cu 0.00062 L1 .00062 CU (ED COPPER) PLANE
0.002 0.002 GFN
1080 - 62%RC 0.0025 PREPREG/BOND
1080 - 62%RC 0.0025 PREPREG/COVER
- .001 Adh/.001 Kap
0.00062 L2 .00062 CU (RA COPPER) SIGNAL
0.003
0.00062 L3 .00062 CU (RA COPPER) PLANE
1080 - 62%RC 0.0025 PREPREG/COVER
1080 - 62%RC 0.0025 PREPREG/COVER
- .001 Adh/.001 Kap/.001 Adh
0.00062 L4 .00062 CU (RA COPPER) SIGNAL
0.003
0.00062 L5 .00062 CU (RA COPPER) PLANE
1080 - 62%RC 0.0025 PREPREG/COVER
.001 Adh/.001 Kap
1080 - 62%RC 0.0025 PREPREG/BOND
Air Gap
.001 Adh/.001 Kap
0.00062 L6 .00062 CU (RA COPPER) PLANE
0.002
1080 - 62%RC 0.0025 PREPREG/COVER
1080 - 62%RC 0.0025 PREPREG/COVER
- .001 Adh
0.00062 L7 .00062 CU (RA COPPER) SIGNAL
0.003
0.00062 L8 .00062 CU (RA COPPER) PLANE
1080 - 62%RC 0.0025 PREPREG/COVER
- .001 Adh/.001 Kap
1080 - 62%RC 0.0025 PREPREG/BOND
Air Gap
.001 Adh/.001 Kap
0.00062 L9 .00062 CU (RA COPPER) PLANE
0.002
1080 - 62%RC 0.0025 PREPREG/COVER
1080 - 62%RC 0.0025 PREPREG/COVER
.001 Adh
0.00062 L10 .00062 CU (RA COPPER) SIGNAL
0.003
0.00062 L11 .00062 CU (RA COPPER) PLANE
1080 - 62%RC 0.0025 PREPREG/COVER
- .001 Adh/.001 Kap
1080 - 62%RC 0.0025 PREPREG/BOND
Air Gap
.001 Adh/.001 Kap
0.00062 L12 .00062 CU (RA COPPER) PLANE
0.002
1080 - 62%RC 0.0025 PREPREG/COVER
1080 - 62%RC 0.0025 PREPREG/COVER
- .001 Adh
0.00062 L13 .00062 CU (RA COPPER) SIGNAL
0.003
0.00062 L14 .00062 CU (RA COPPER) PLANE
1080 - 62%RC 0.0025 PREPREG/COVER
- .001 Adh/.001 Kap
1080 - 62%RC 0.0025 PREPREG/BOND
0.002 .002 GFN (CORE)
0.00062 L15 .00062. CU (ED COPPER)
Cu Plate 0.0014 .0014 PLATING (E.D. PLATING)
S/M 0.001 LPI (SOLDERMASK) .0015
NI/AU Plate 0.00013 NI/AU
Rigid Thk. 0.085
THRU VIA
THRU VIA
THRU VIA
THRU VIA
S
X
S
X
S
X
LYR-04 BACKDRILL
LYR-07 BACKDRILL
LYR-10 BACKDRILL
DRILL QTY 1147 88 88 84
DO NOT CUT LAYER N/A L05 L08 L11
SUBCOMPOSITE 1
SUBCOMPOSITE 2
SUBCOMPOSITE 3
SUBCOMPOSITE 4

Stack-up



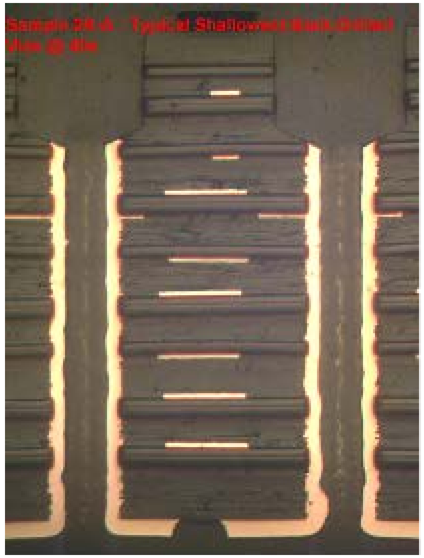


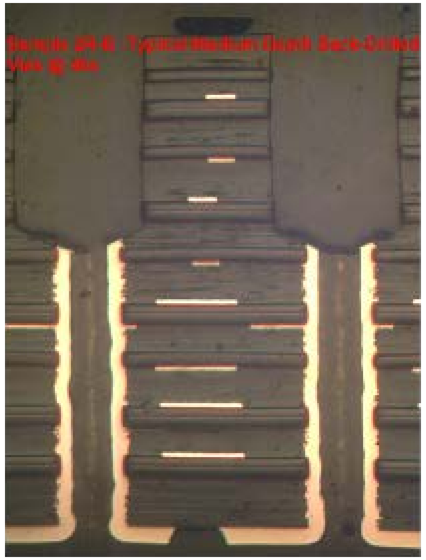
Cost Model

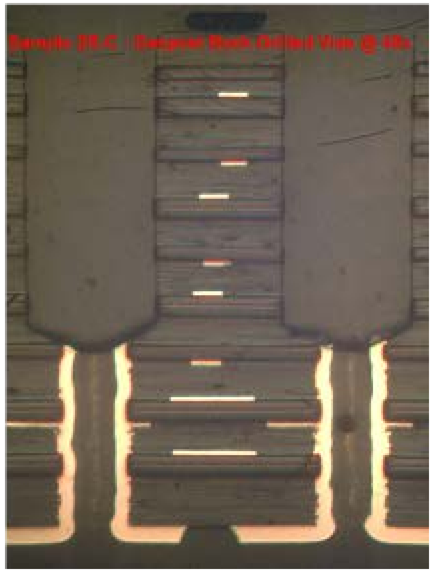
- Rectangular shape facilitated good panelization
  - Rows allowed for bookbinder construction
- Costs inputs collaboratively reviewed during development
- Initial production: 28 up on 18x24 panel
- Qualified large panel: 60 up on 24x36 panel
- Qualified low cost geography manufacturing site

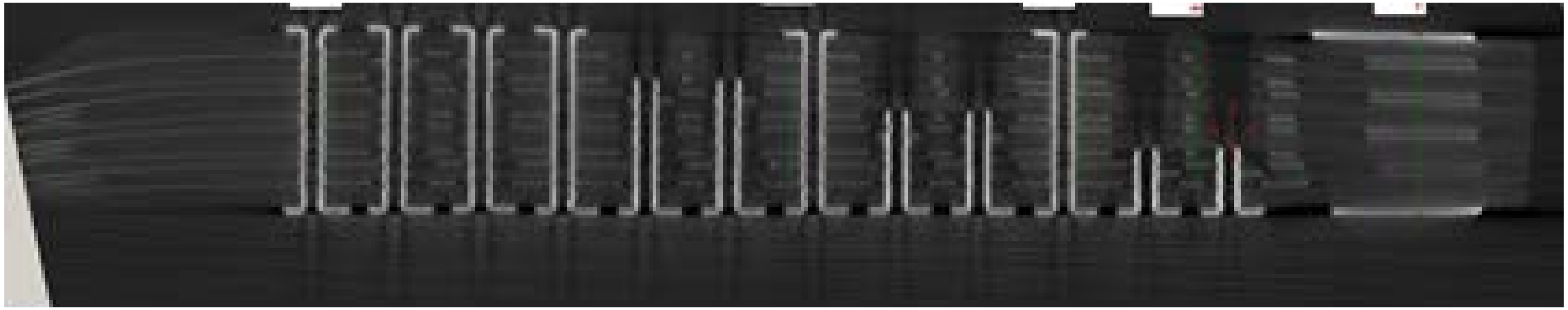
Backdrill

- Backdrill added to improve signal integrity margin
- 3 via depths backdrilled
  - 260 vias



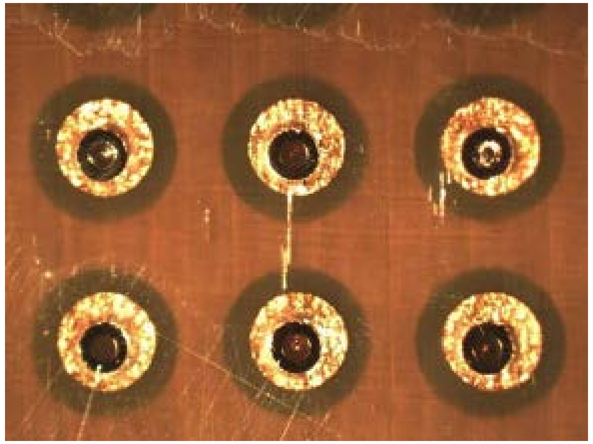


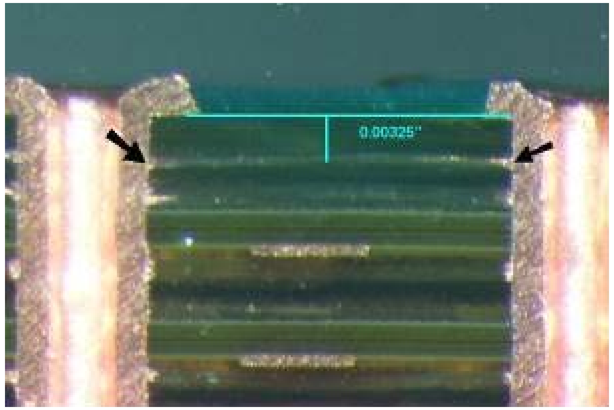


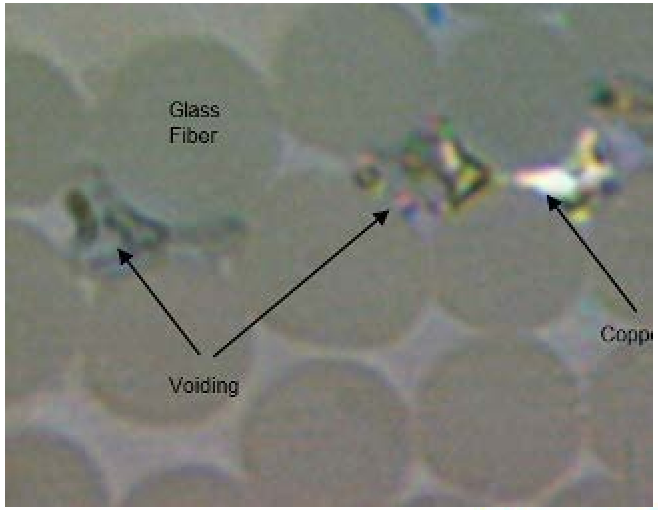


Conductive Anodic Filament Testing

- Conductive Anodic Filament (CAF) concern
  - 1mm via pitch
  - Low flow/no flow pre-preg required to control epoxy flow from rigid area
- Early test fails

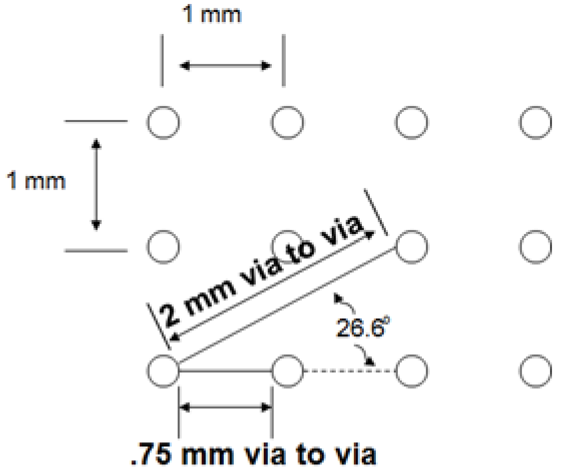


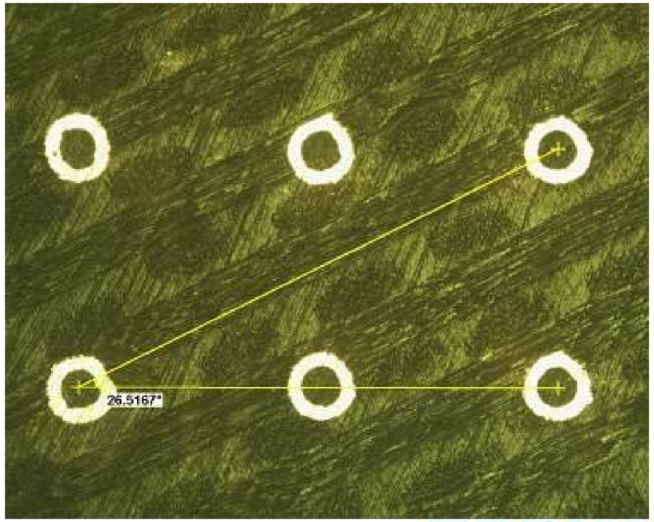




Conductive Anodic Filament Testing

- Team consisting of pre-preg supplier, flex manufacturer and end user reviewed options.
  - Program schedule constraints
- Pre-preg rotation successfully tested
  - Increases effective via to via distance
  - Pre-preg rotated not parts to facilitate bookbinder manufacturing processes

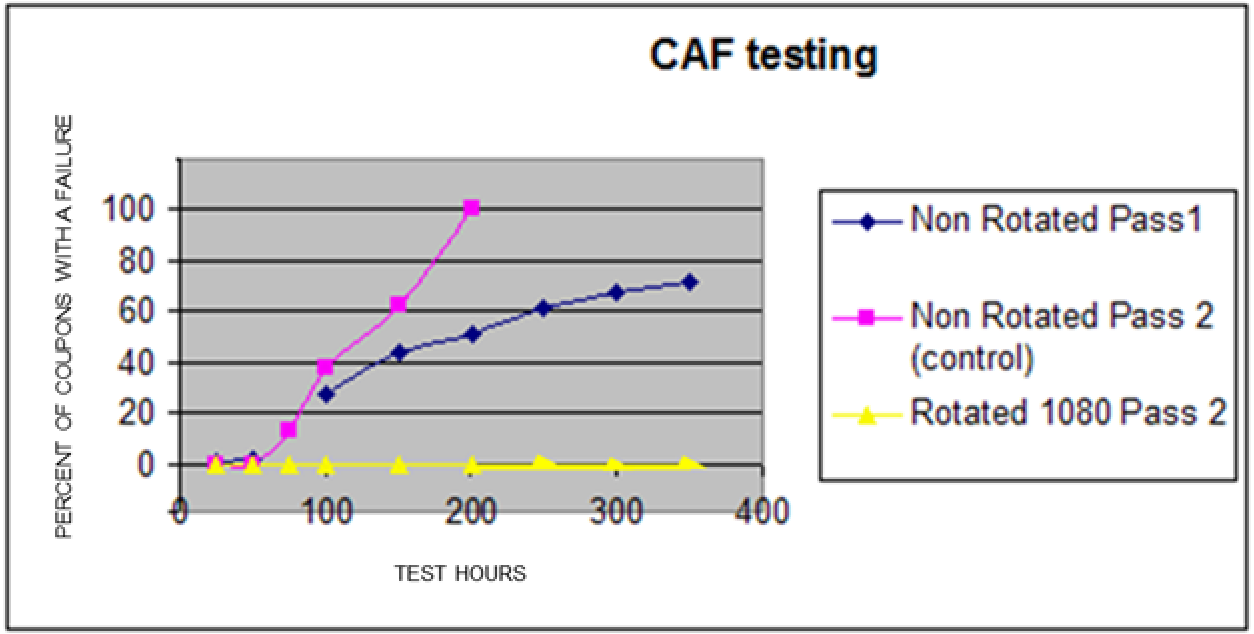




FORWARD THINKING
FOR TOMORROW'S TECHNOLOGY

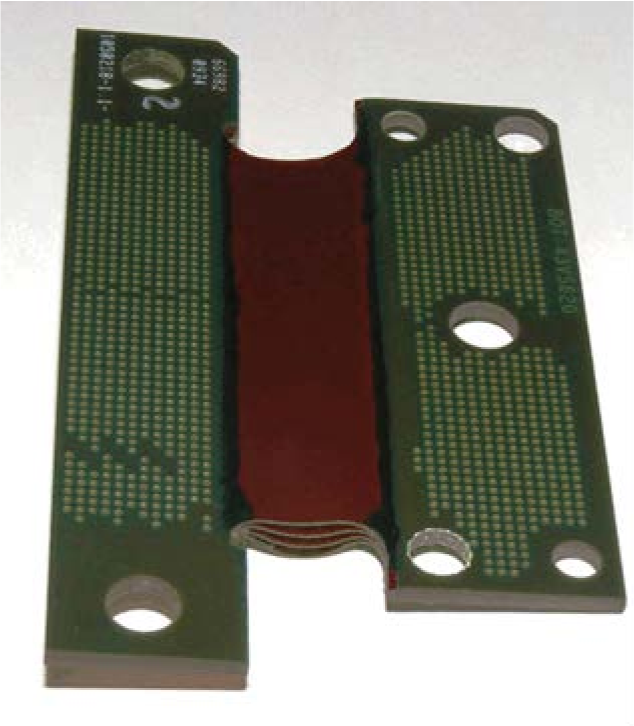
Conductive Anodic Filament Testing

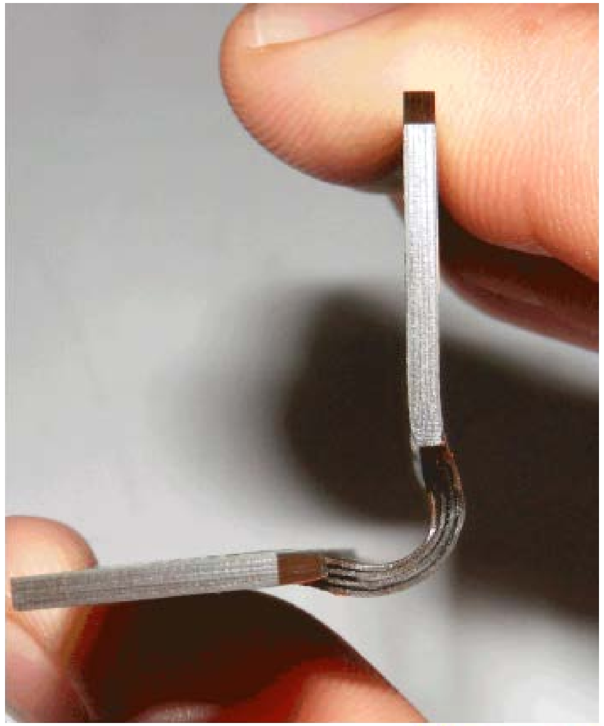
- Rotated pre-preg and non rotated tested
  - Non rotated pre-preg fails occurred within 50 hours of testing
  - Initial rotated pre-preg testing successful
    - Subsequent testing with backdrilled vias, multiple sites successful



Final Implementation

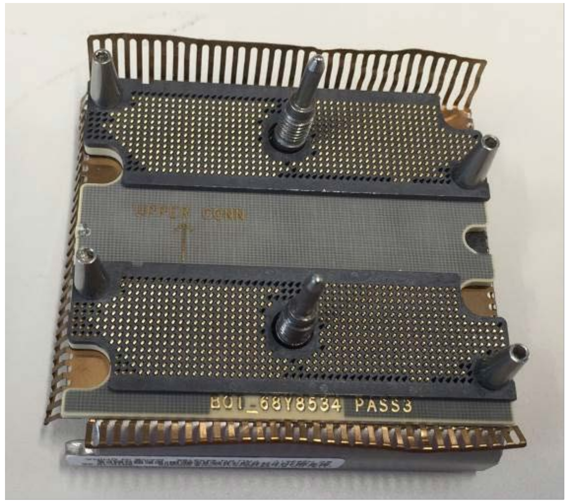
- Bookbinder rigid flex allowed for tight 90 degree bend





Final Implementation

- Mechanical hardware aligned LGA contacts between rigid flex and scalability cards while providing required normal force



Final Implementation

- Successfully implemented in 2 and 4 blade server systems
- Collaboration was key

Thank you

Questions?