SIITME 2017

Rigid Flex Circuit s
A Technological Overview

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Outline

- What is a Rigid Flex Circuit?
- Why Use Rigid Flex Circuits?
- Rigid Flex Issues
- Representative Rigid Flex Constructions
- Some Rigid Flex Applications
- Future of Rigid Flex?
- Summary
- Further reading

What is Rigid Flex?

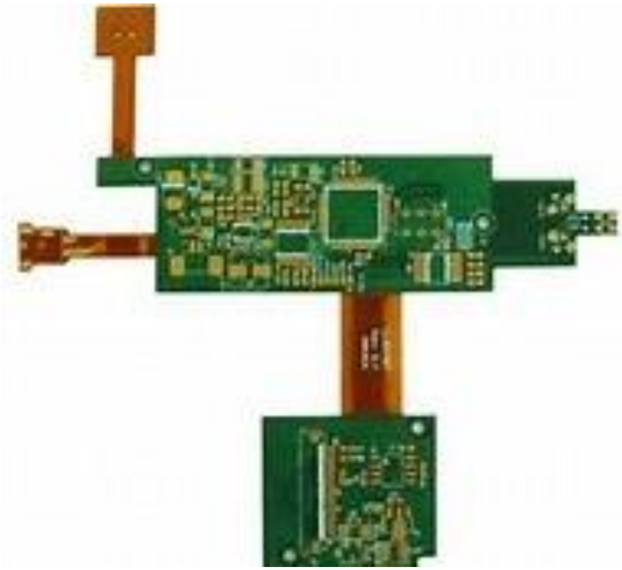
What is a Rigid Flex Circuit?

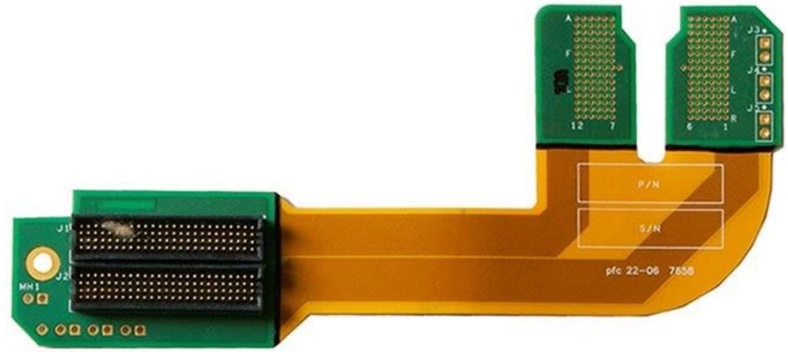
Rigid flex circuits are a hybrid structure of rigid and flexible PCBs

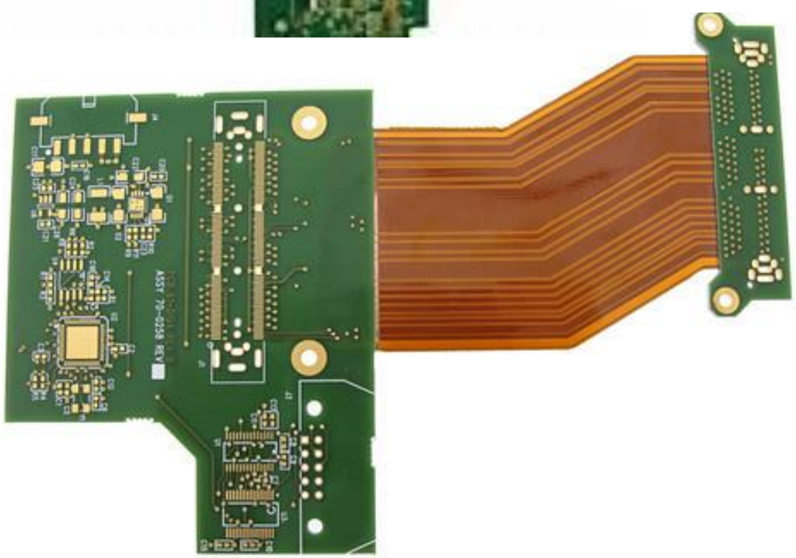
Rigid and flexible circuits are integrated into a unitary interconnection structure to gain special advantages .

The structures can vary widely in terms of materials and layout but in general, the most common materials are polyimide for the flexible circuit portions and FR4 or polyimide laminates for the rigid portions

Some examples…







Why Rigid Flex?

Why Rigid Flex?

Increased Interconnection Density in the 3rd Dimension

- The demand for increased electronics in an ever smaller space is driving more design to consider volumetric solutions and 3D interconnection is the a key capability for rigid flex

Reduced Assembly Costs

- Rigid flex circuits integration of flexible areas with rigid elements which support components and connectors can significantly reduce the cost

Elimination of Assembly Errors

- Errors in assembly are prevented in the design process thus eliminating operator touch errors.

Weight Reduction

- Significant reduction in assembly weight can be achieved

Improved Reliability

- Elimination of numerous solder interconnections yields improved reliability

Rigid Flex Issues

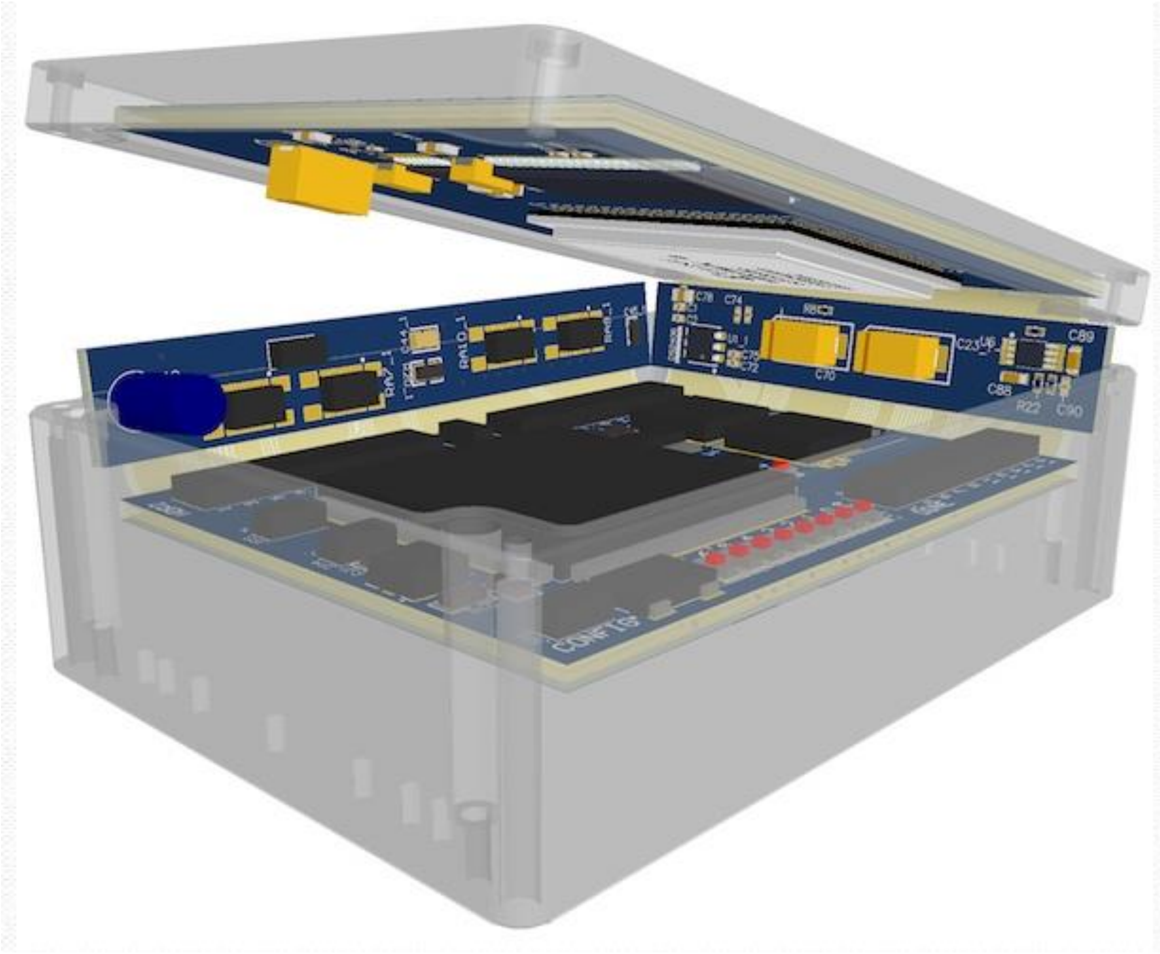
Rigid Flex Issues

In spite of the advantages, rigid flex circuits also have some drawbacks

- The overall cost is greater (in small volumes)
- Design and process planning are often engineering time intensive
- Use of modeling is very important to first pass success
- PI flex materials more expensive than FR4 laminates (~ 3X)
- Low flow adhesives normally are more costly than epoxy prepreg
- Coverlayers and flexible cover coats also cost more than standard solder masks
- Manufacturing is labor intensive, some equipment is unique and rigid flex is not readily adapted to automation.

Still from a system perspective, rigid flex can save time and money

CAD Modeling Saves Time and Reduces Errors

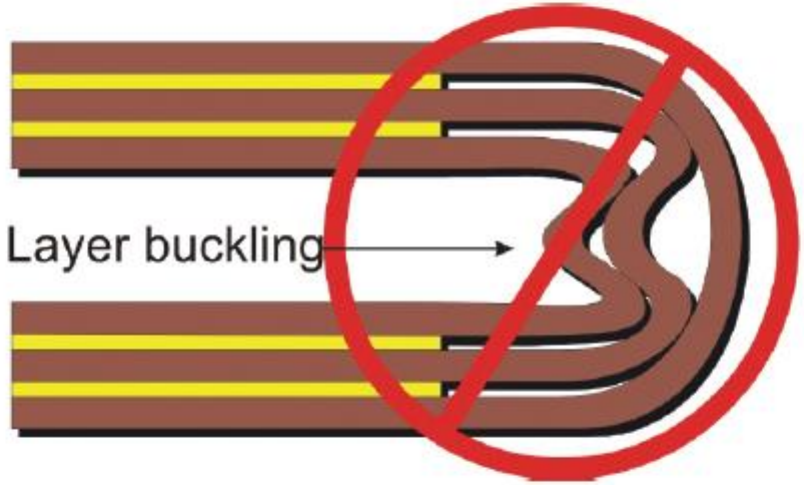


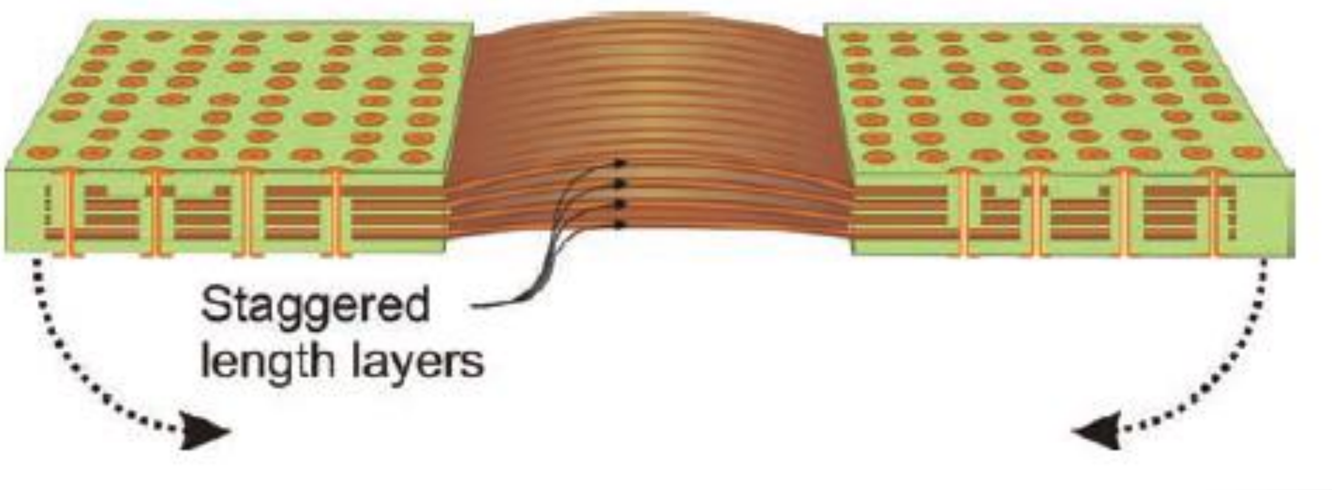
Design Concerns

Rigid Flex Circuits Require Special Knowledge and Attention

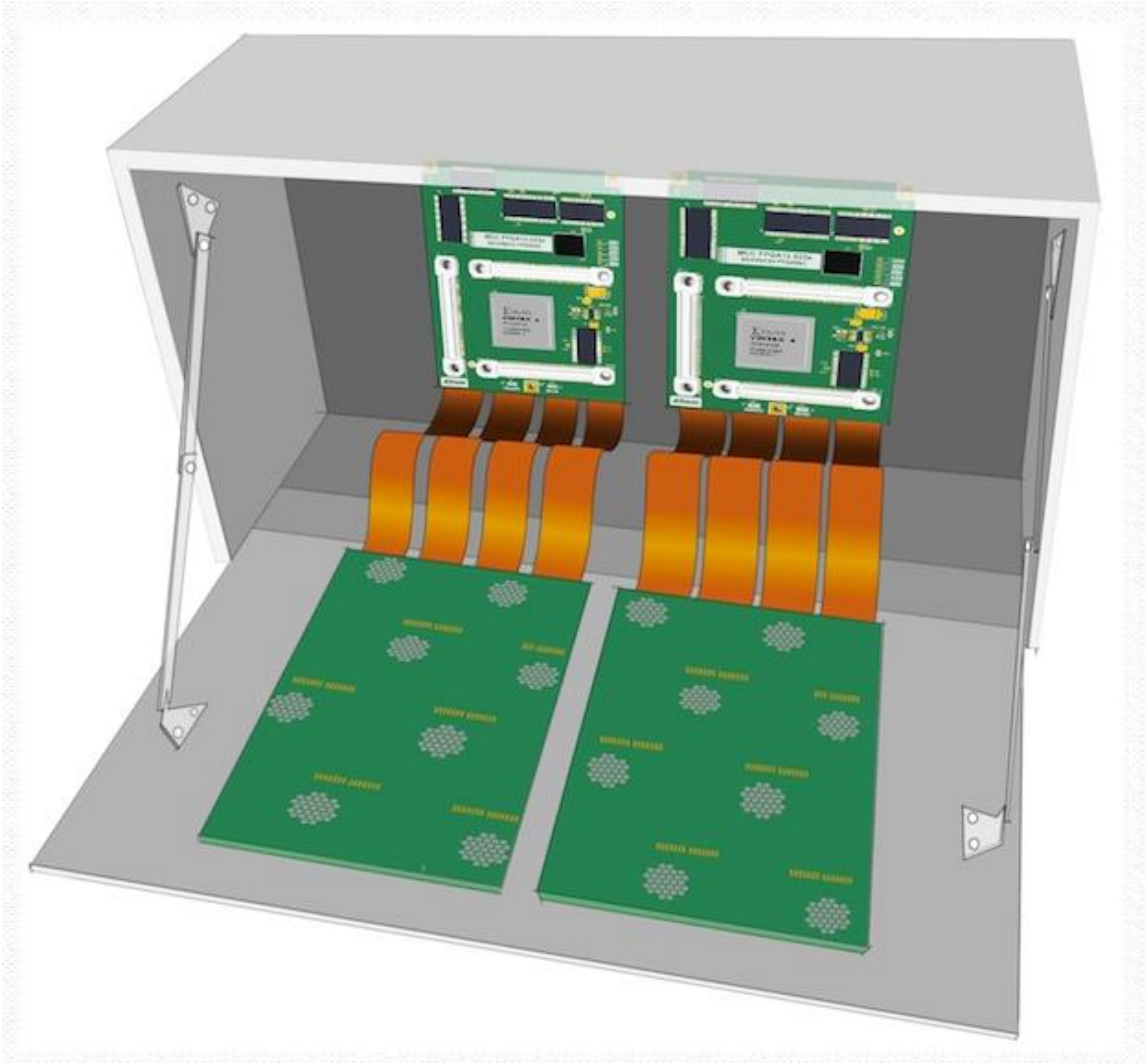
- **Material choices will impact cost and performance**
  - Electrical and mechanical performance is gated by material
  - The designer must understand these issues and make tradeoff decisions when required
- **Material choices will also effect manufacturing**
  - Copper thickness, dimensional stability, processing challenges
- **Dealing with transition areas requires special attention**
  - Transitions between rigid and flexible areas are critical and frequently a site where failures occur.
- **Rigid flex circuits often require special features to facilitate installation into the product or application**
  - Book binder constructions are unique
- **Consideration must be given to field service**

Avoidance of Buckling by Design





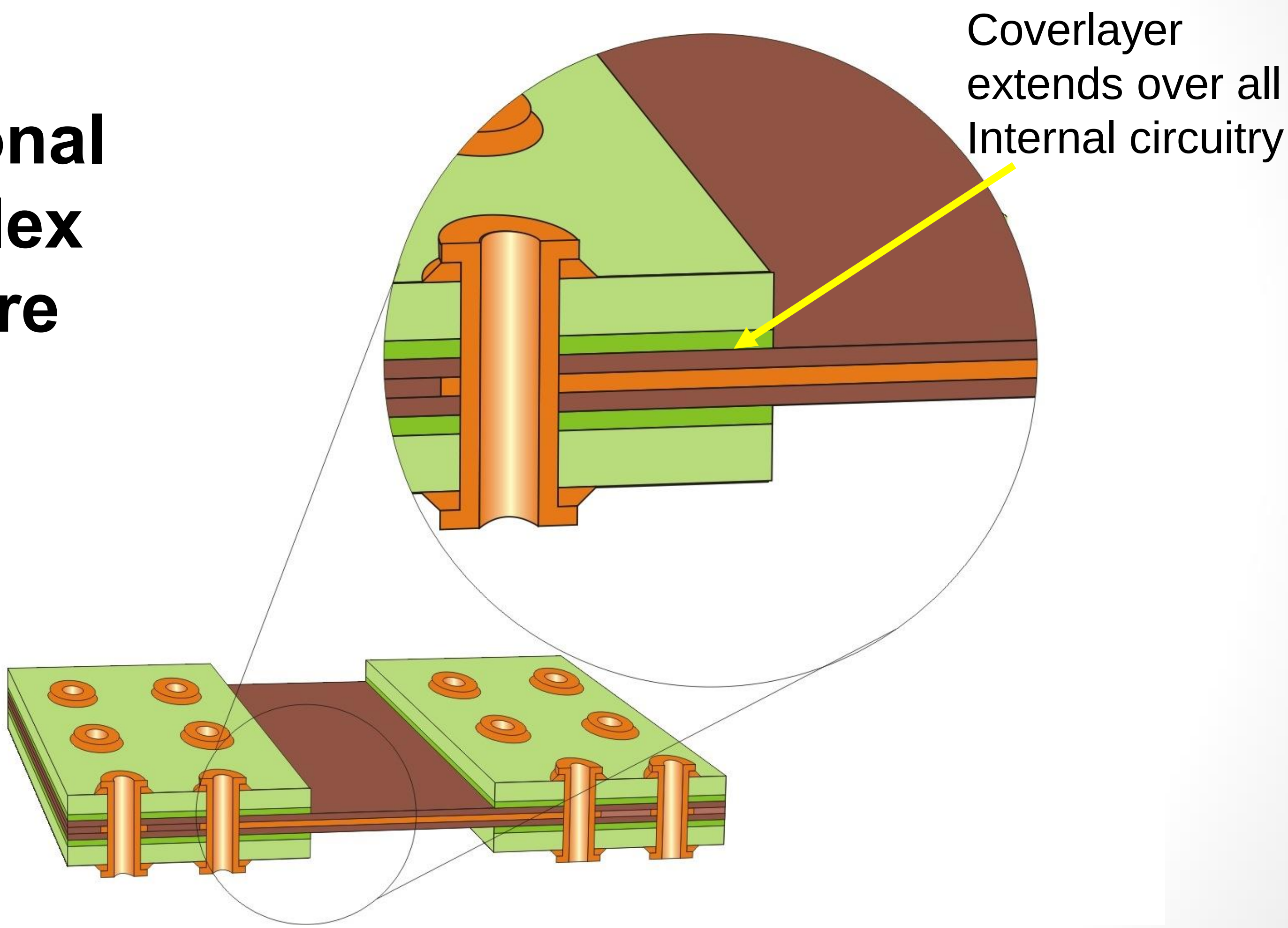
Consider Field Service Access



Rigid Flex Construction Variations

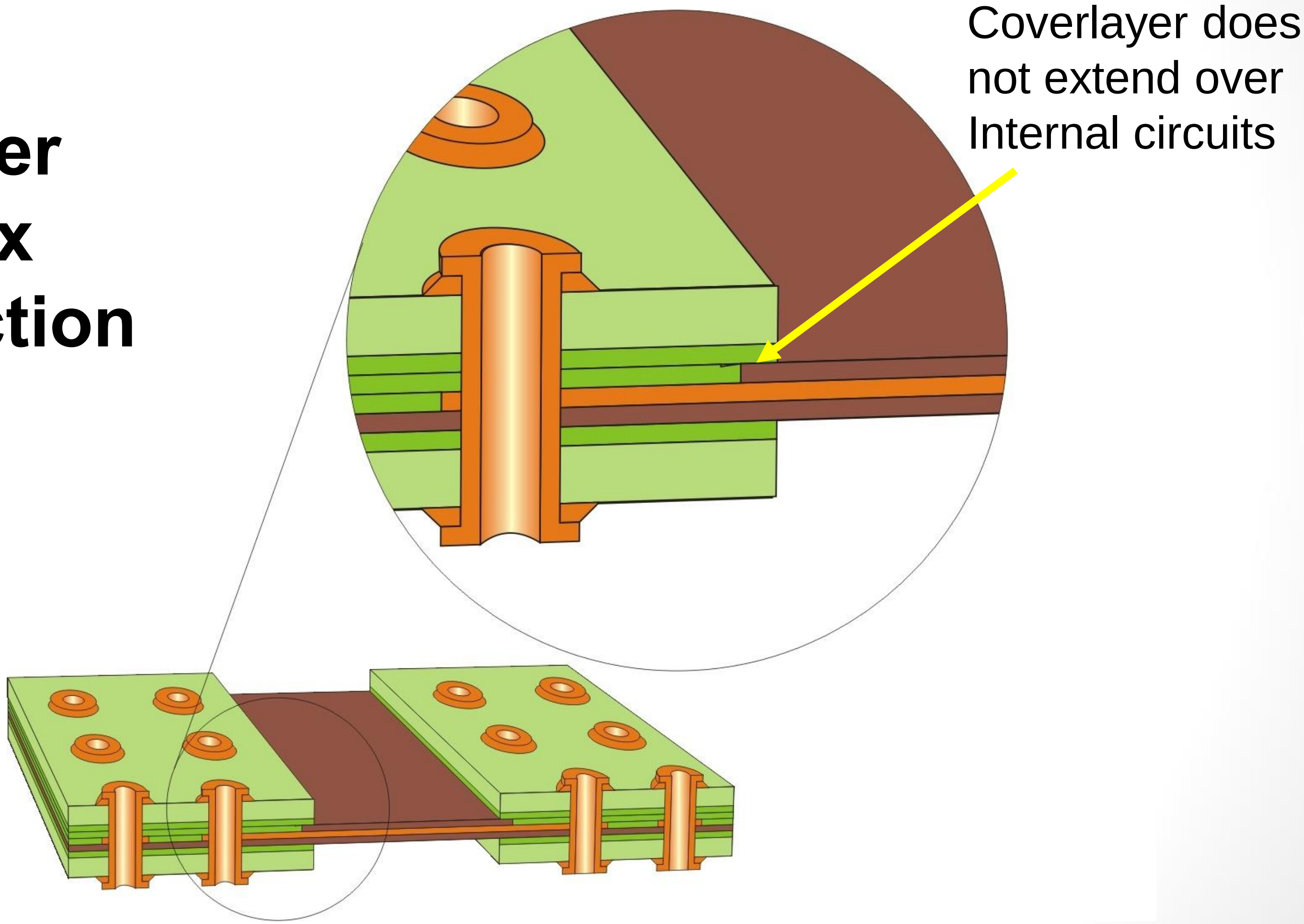
Exemplary Rigid Flex Constructions

Traditional Rigid Flex Structure



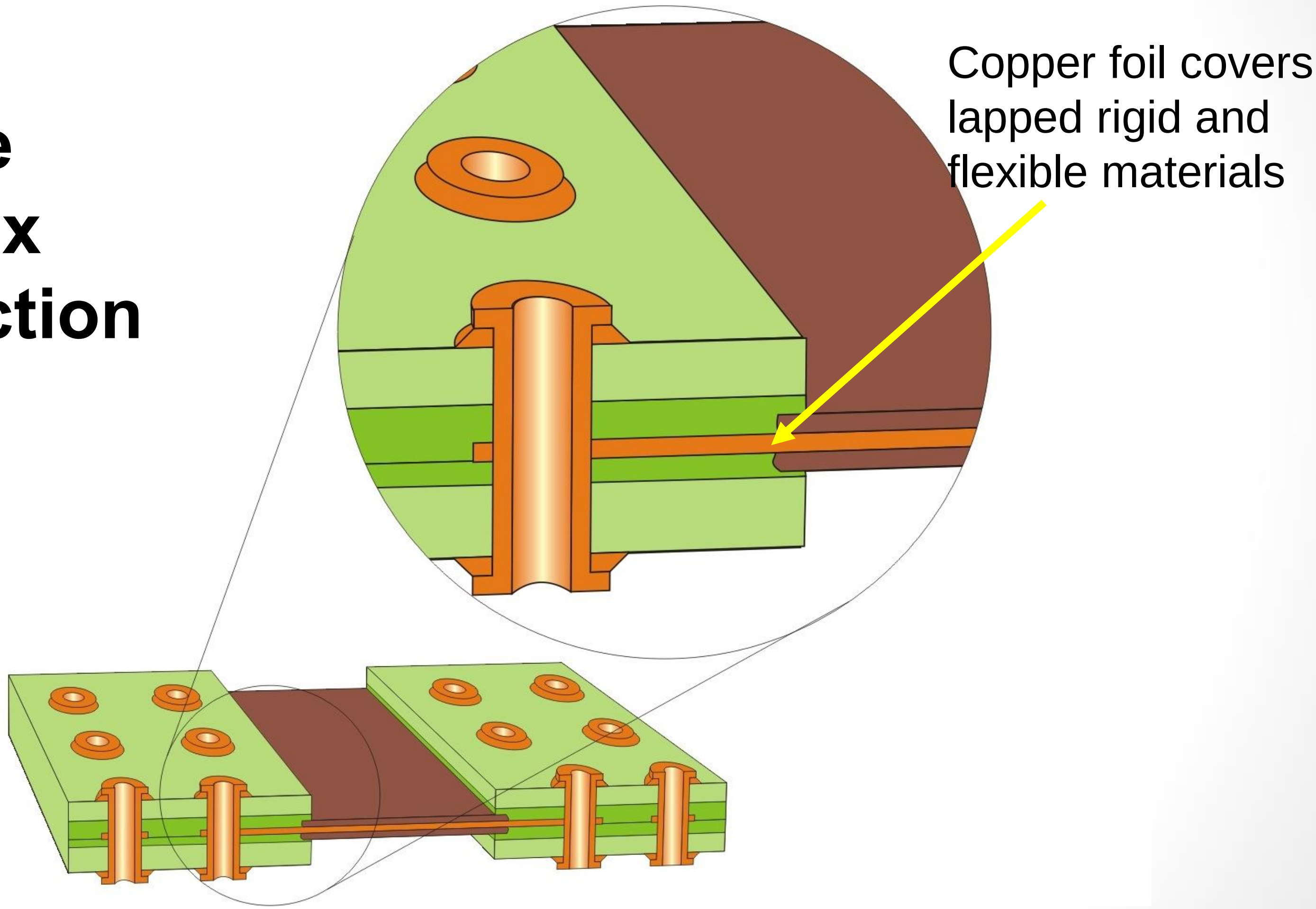
Exemplary Rigid Flex Constructions

Short Coverlayer Rigid Flex Construction



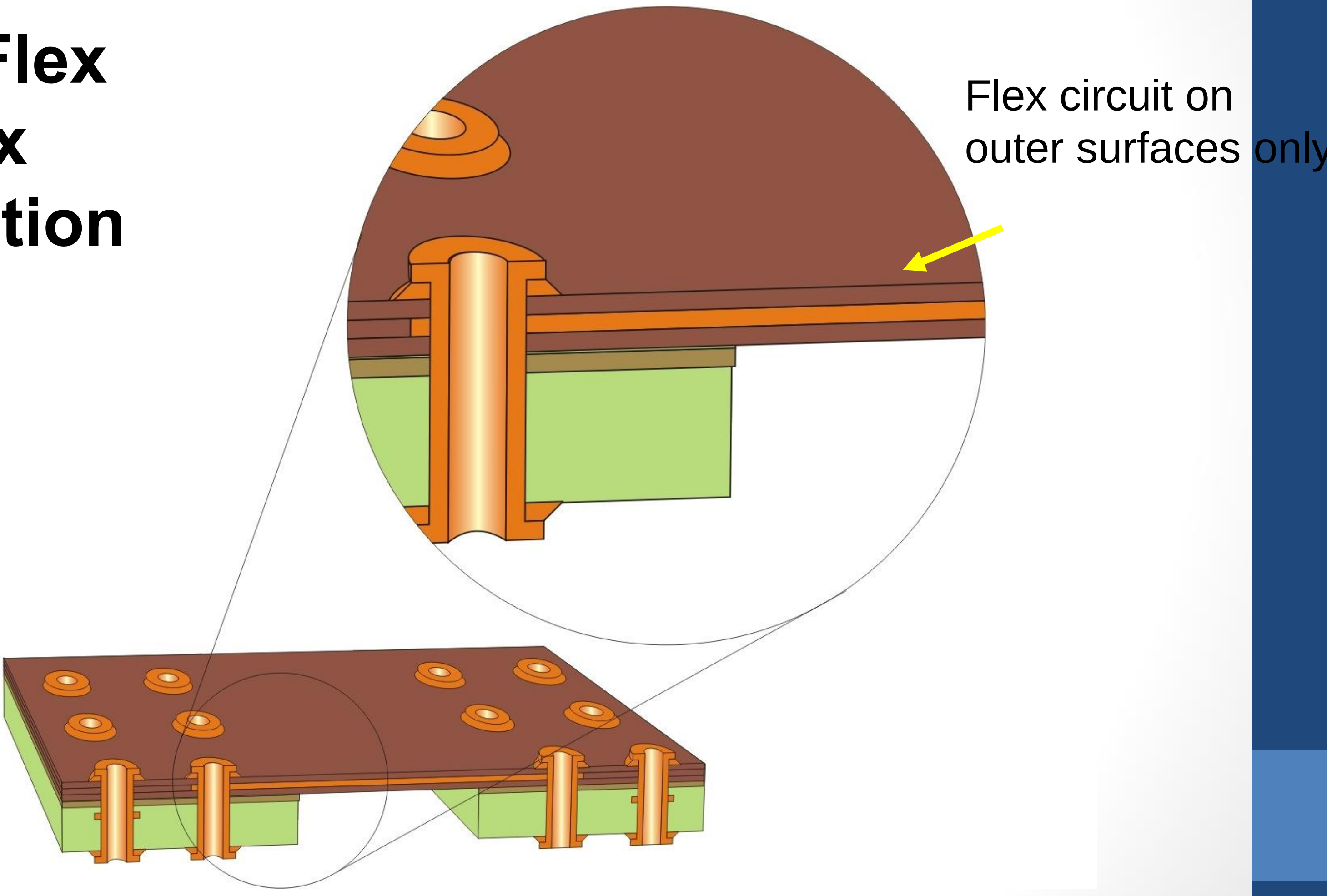
Exemplary Rigid Flex Constructions

Hybrid Laminate Rigid Flex Construction



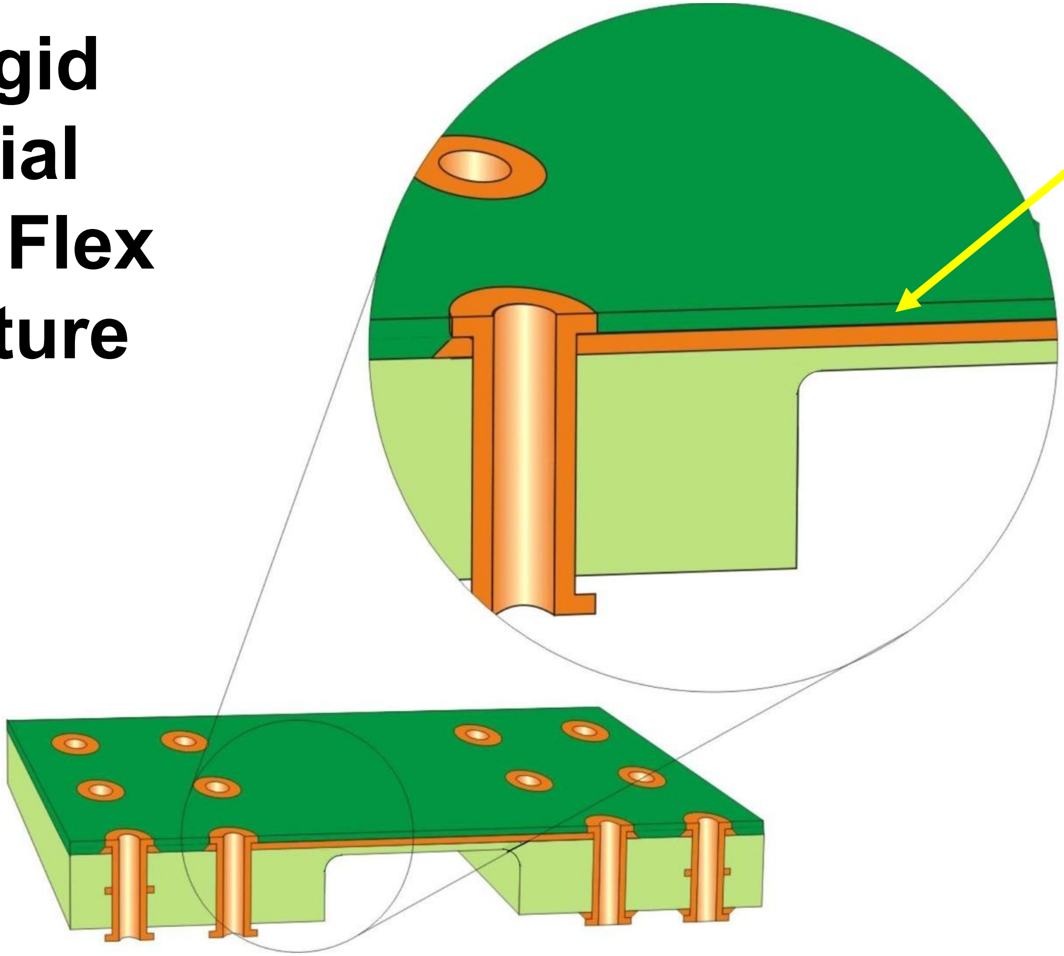
Exemplary Rigid Flex Constructions

Surface Flex Rigid Flex Construction



Exemplary Rigid Flex Constructions

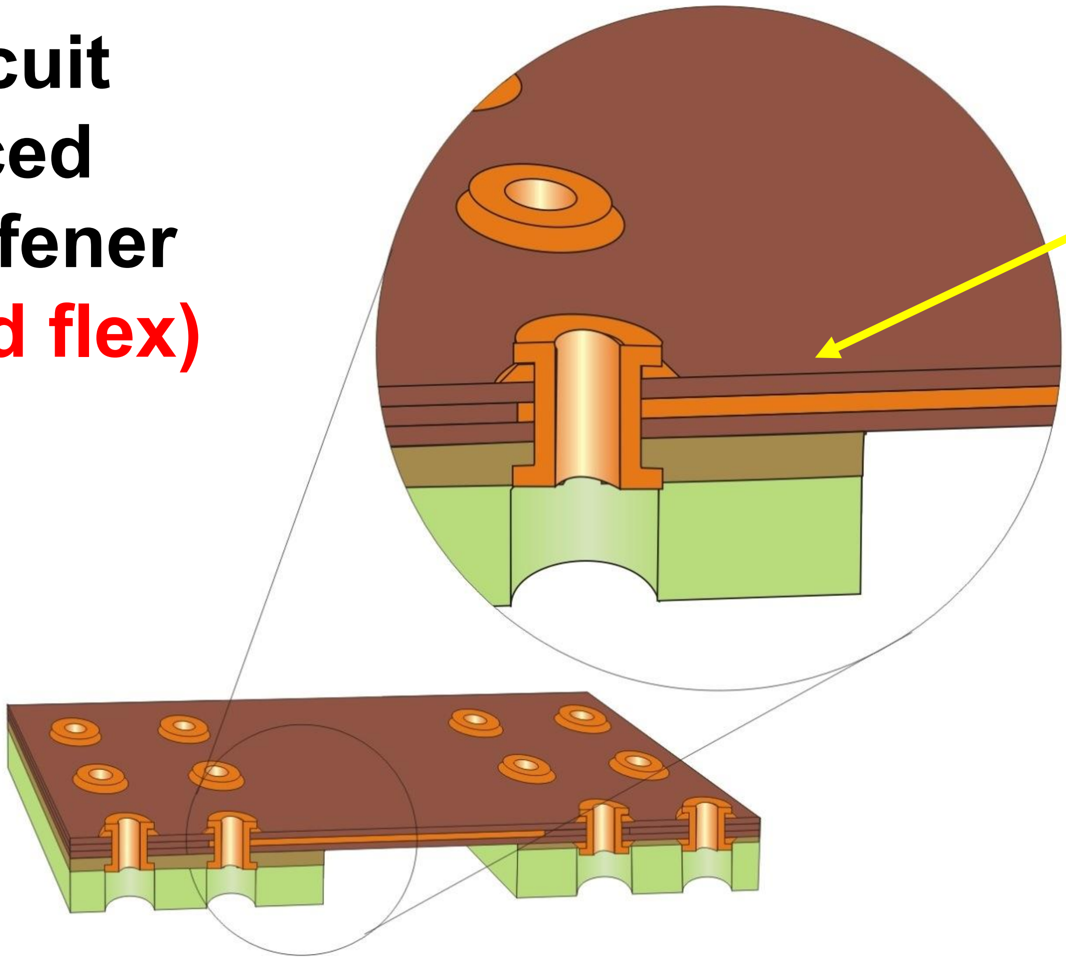
All Rigid Material Rigid Flex Structure



Rigid laminate material routed to thickness that will bend using suitable radius. Flexible coverlay normally needed

Reinforced Flex Construction

Flex Circuit Reinforced with Stiffener
(not rigid flex)



Flex circuit bonded to rigid stiffener

Other Solutions

- Very thin FR4 circuits can provide some flexiblity.
- Semi-rigid laminates with non woven reinforcements and low modulus thermoplastic resins (e.g. PTFE, polyester etc.) have been explored in the past and could be revisited.
- A caveat… when it comes to assembly high temperature lead-free solders will be cause for continuing concern to the industry owing to the higher Z axis CTE inherent with most rigid flex structures.

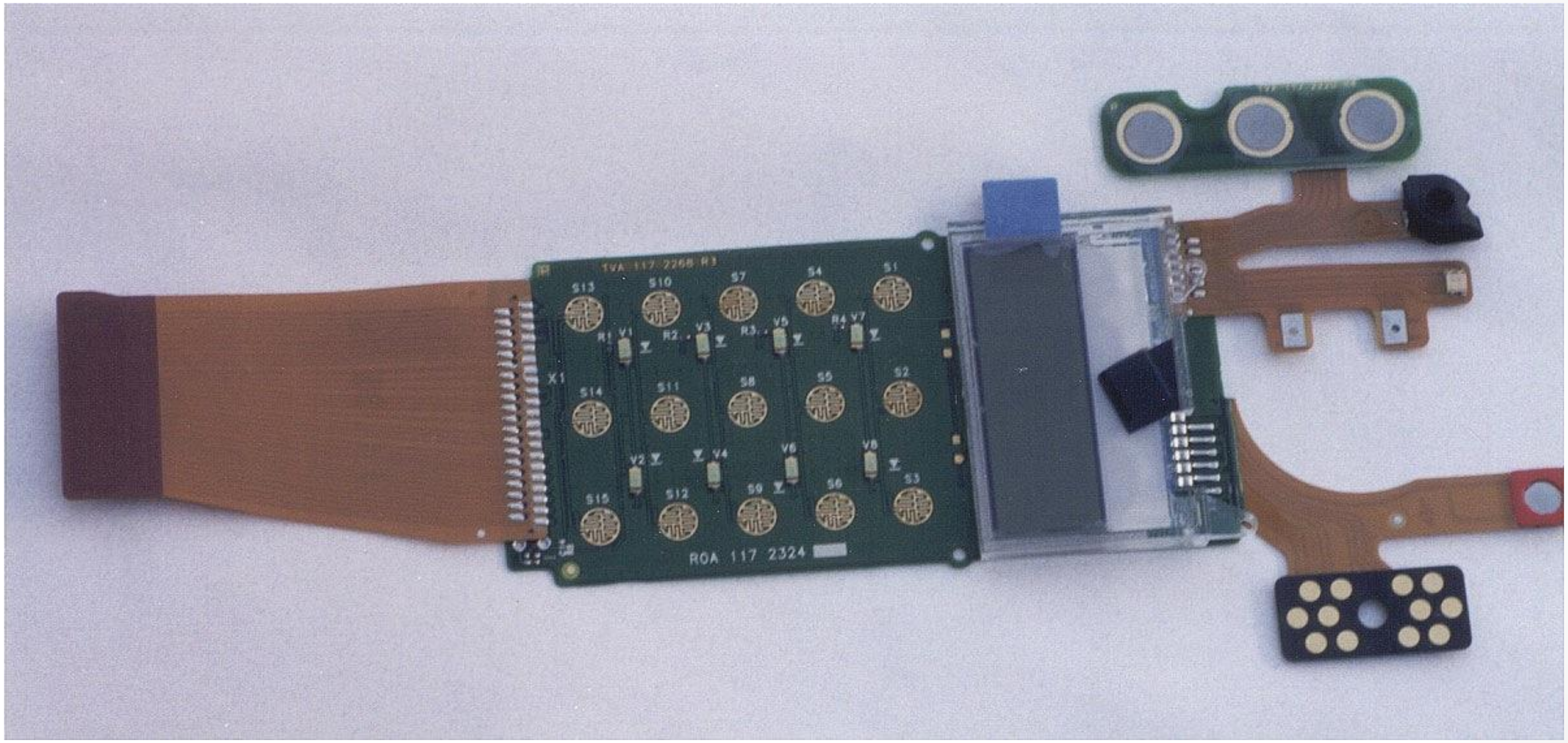
Rigid Flex Market and Applications

Rigid Flex Circuit Applications

Rigid flex circuits were developed largely to replace bulky and heavy wire harnesses but have since migrated to many new areas of application

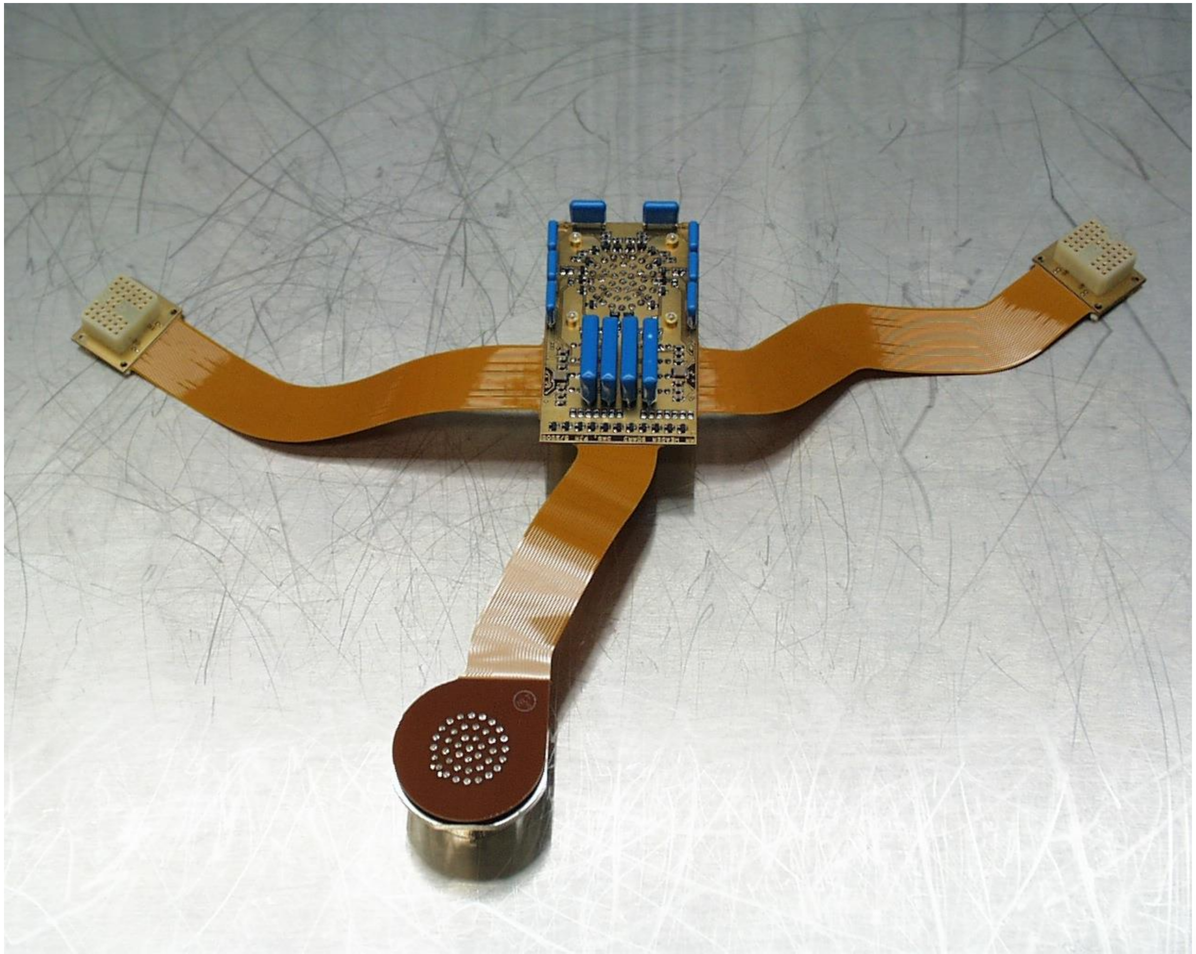
- Clam shell type mobile phones
- Mobile phone camera modules
- Missiles and weapons systems
- Camera monitoring systems
- Electrical test equipment
- Lap top computers
- Digital cameras
- Hearing Aids
- Satellites

Hand Held Key Board Assembly



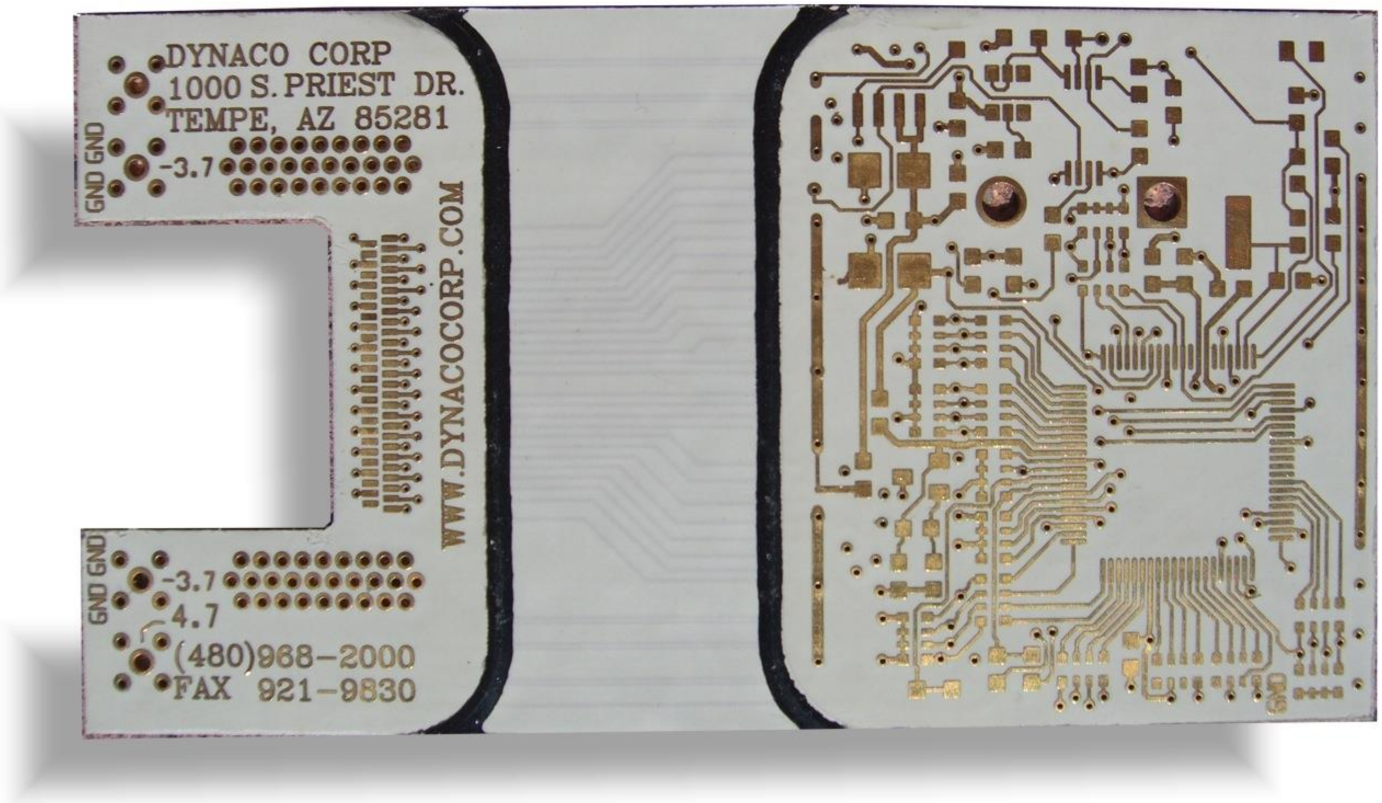
Source : **Interconnect Systems, Inc.**

CCD Detector



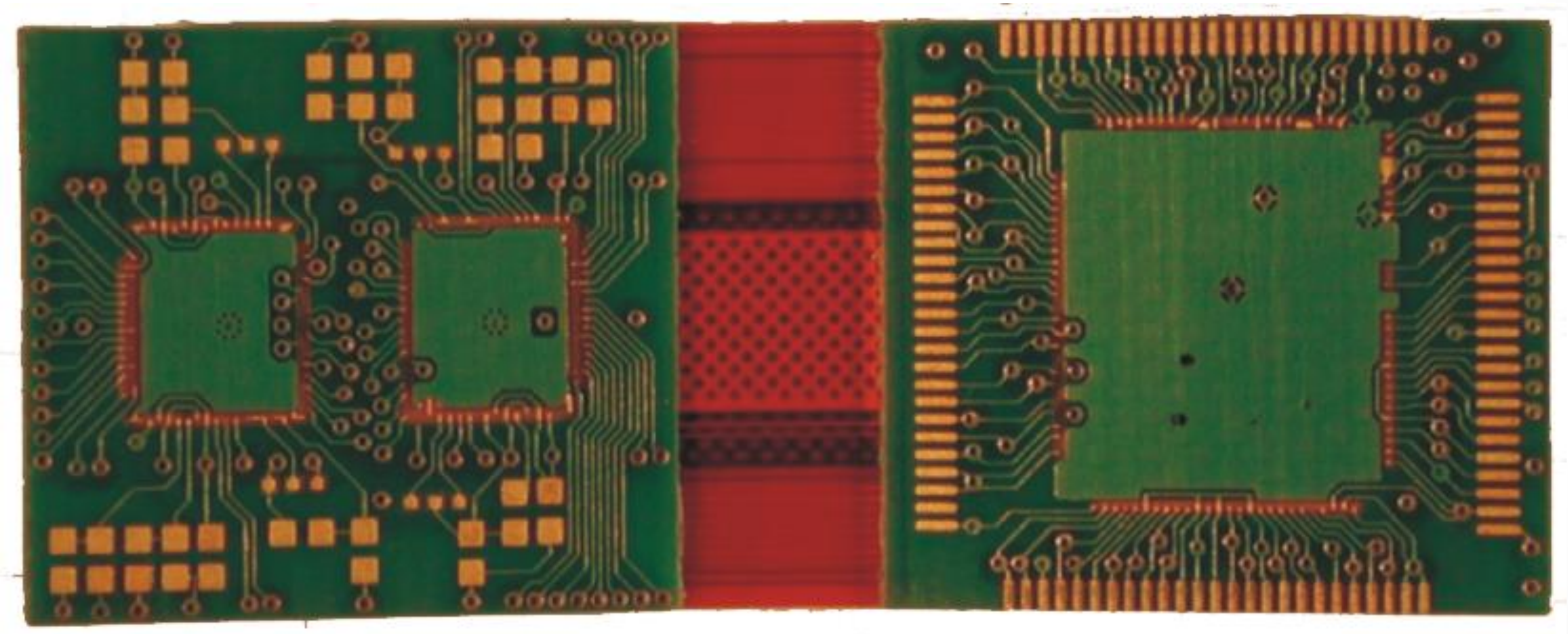
Source : University of Texas

Liquid Crystal Polymer Rigid Flex



Source : Dynaco Corp.

Chip on Board Rigid Flex



Source : University of Pennsylvania

Future of Rigid Flex

What is the Future of Rigid Flex?

- Integration of rigid and flex should see increased use and application in the future
- Each technology has intrinsic benefits and the synergy of the combination is highly compelling
- New structures will offer and should provide significant opportunities and improvements over current generation solutions.
- What follows is a description of a prospective way of making rigid flex circuit assemblies with minimal soldering and/or where the soldered elements are suitably protected from damage.

Proposed Process for the Low Cost Manufacture of Highly Reliable Rigid Flex Assemblies

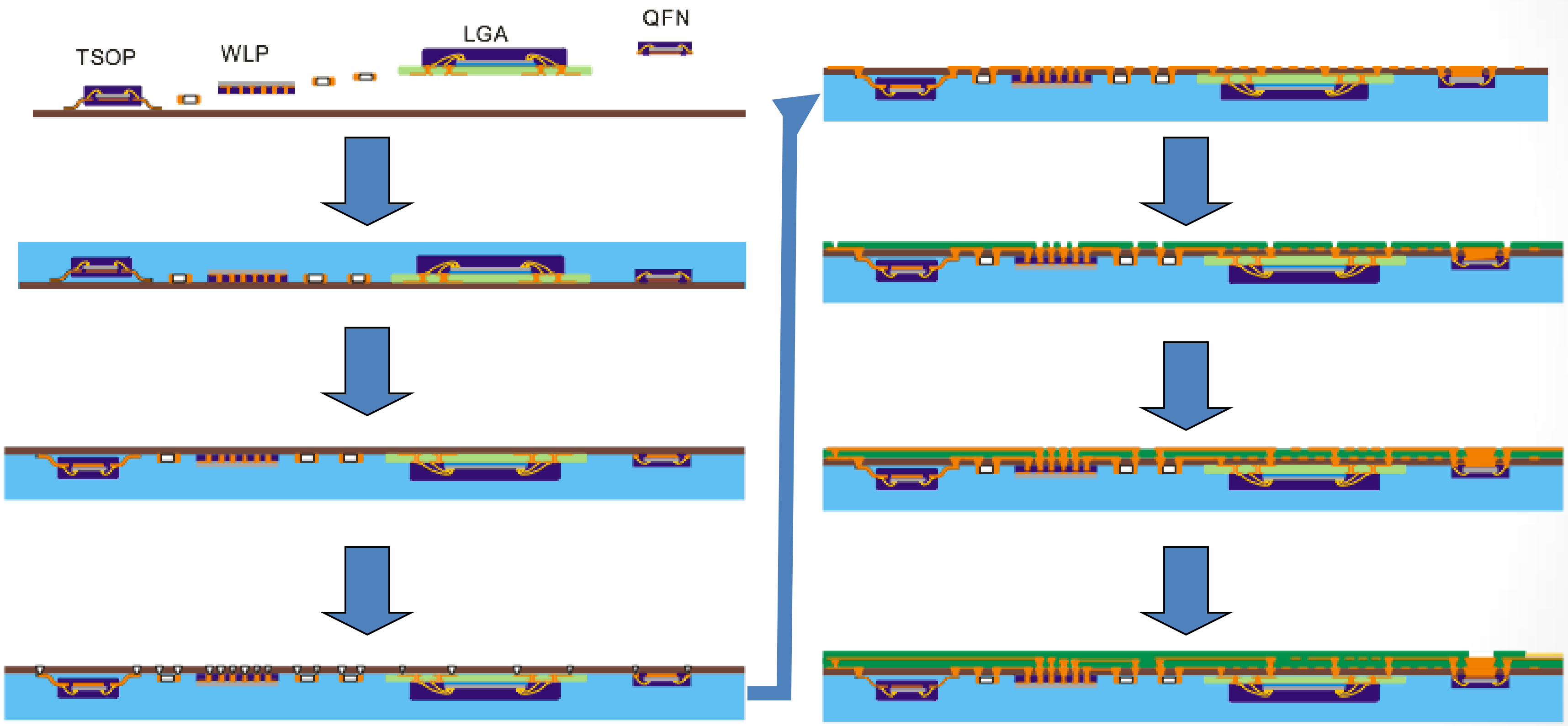
Background

- Rigid flex technology offers significant benefit to a broad range of products.
- One of the problems, however is that the assemblies must be soldered and high temperature lead free soldering can damage both the circuit and the components
- The common failure for most surviving assemblies is typically a solder joint
- A process which eliminates soldering where possible should greatly improve reliability.

Process Background

- The Occam Process is predicated on the elimination of solder and desirably uses only components with a copper finish, unfortunately nearly all components presently have some sort of finish.
- While ideally solder will not be applied at some point in the future, to obtain immediate benefit of the structures that will be shown, some accommodation must be made for solder processing

Basic Occam Process Sequence



Patents issued and pending

Traditional Process Steps

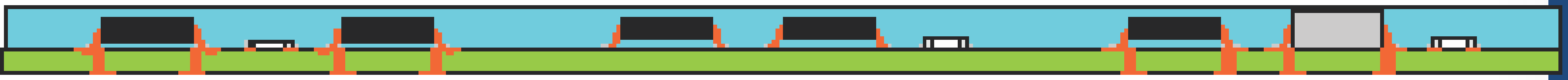
Design PCB Assembly	Fabricate PCB (multilayer)	Assemble PCB
1. Create schematic 2. Indentify components 3. Layout circuits 4. Validate signal integrity 5. Validate design DfM 6. Validate design DfR 7. Validate design DfE	1. Verify RoHS compliance 2. Cut core laminas to size & tool 3. Clean and coat with resist 4. Image and develop resist 5. Etch and strip resist 6. Treat exposed copper 7. AOI or visual inspect layers 8. Cut B-stage to size and tool 9. Lay up core and B-stage 10. Laminate 11. X-ray inspect (optional) 12. Drill (stack height varies) 13. Desmear or etchback 14. Sensitize holes 15. Plate electroless copper 16. Clean and coat with resist 17. Image an develop resist 18. Pattern plate copper 19. Pattern plate metal resist 20. Strip plating resist 21. Etch base copper 22. Clean and coat with soldermask 23. Image and develop 24. Treat exposed metal (options) 25. Solder, NiAu, Sn, Ag, OSP, etc. 26. Electrical test 27. Route to shape 28. Package 29. Ship	1. Procure components 2. Verify RoHS compliance 3. Verify component solderability 4. Verify component MSL number 5. Kit components 6. Procure PCBs 7. Verify RoHS compliance 8. Verify PCB solderability 9. Verify PCB High Temp capability 10. Design solder stencil & purchase 11. Develop suitable reflow profile 12. Track component exposure (MSL) 13. (Rebake components as required) 14. Position PCB & stencil solder paste 15. (monitor solder paste) 16. Inspect solder paste results 17. (height and skips) 18. Dispense glue dots (optional) 19. Place components 20. Inspect for missing parts 21. Reflow solder 22. Repeat Steps 13-18 if two sided assy 23. (second set of fixtures required) 24. Perform hand assembly as required 25. (odd sized or temperature sensitive) 26. Clean flux from surface and under 27. Verify low standoff devices 28. Test cleanliness 29. Underfill critical components 30. X-ray inspect soldered assembly 31. Identify shorts, opens, voids, missing 32. Electrically test 33. Rework and repair as needed 34. Package 35. Ship

Modified Process Steps

Design PCB Assembly	Fabricate PCB (multilayer)	Assemble PCB
1. Create schematic	1. Ver[redacted]	1. Procure components
2. Indentify components	2. Cut[redacted]	2. Verify[redacted]
3. Layout circuits	3. Cle[redacted]	3. Verify[redacted]
4. Validate signal integrity	4. Ima[redacted]	4. Verify[redacted]
5. Validate design DfM	5. Etc[redacted]	5. Kit components
6. Validate design DfR	6. Tre[redacted]	6. Procu[redacted]
7. Validate design DfE	7. AO[redacted]	7. Verify[redacted]
	8. Cut[redacted]	8. Verify[redacted]
	9. Lay[redacted]	9. Verify[redacted]
	10. Lar[redacted]	10. Desig[redacted]
	11. X-r[redacted]	11. Deve[redacted]
	12. Drill (stack height varies)	12. Track[redacted]
	13. Desmear or etchback	13. (Reba[redacted]
	14. Sensitize holes	14. Posit[redacted]
	15. Plate electroless copper	15. (mon[redacted]
	16. Clean and coat with resist	16. Inspe[redacted]
	17. Image an develop resist	17. (heig[redacted]
	18. Pattern plate copper	18. Dispe[redacted]
	19. Pattern plate metal resist	19. Place components
	20. Strip plating resist	20. Inspect for missing parts
	21. Etch base copper	21. Reflo[redacted]
	22. Clean and coat with soldermask	22. Repe[redacted]
	23. Image and develop	23. (seco[redacted]
	24. Treat exposed metal (options)	24. Perform hand assembly as required
	25. So[redacted]	25. (odd[redacted]
	26. El[redacted]	26. Clear[redacted]
	27. Route to shape	27. Verif[redacted]
	28. Pac[redacted]	28. Test[redacted]
	29. Shi[redacted]	29. Unde[redacted]
		30. X-ray[redacted]
		31. Ident[redacted]
		32. Electrically test
		33. Rewo[redacted]
		34. Package
		35. Ship

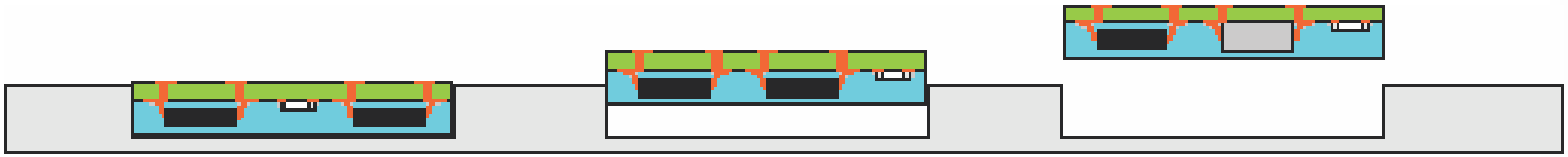
Assemble Functional Islands Using Solder on Standard PCB Panel

Encapsulate Assembly on Component Side to Provide Uniform Height

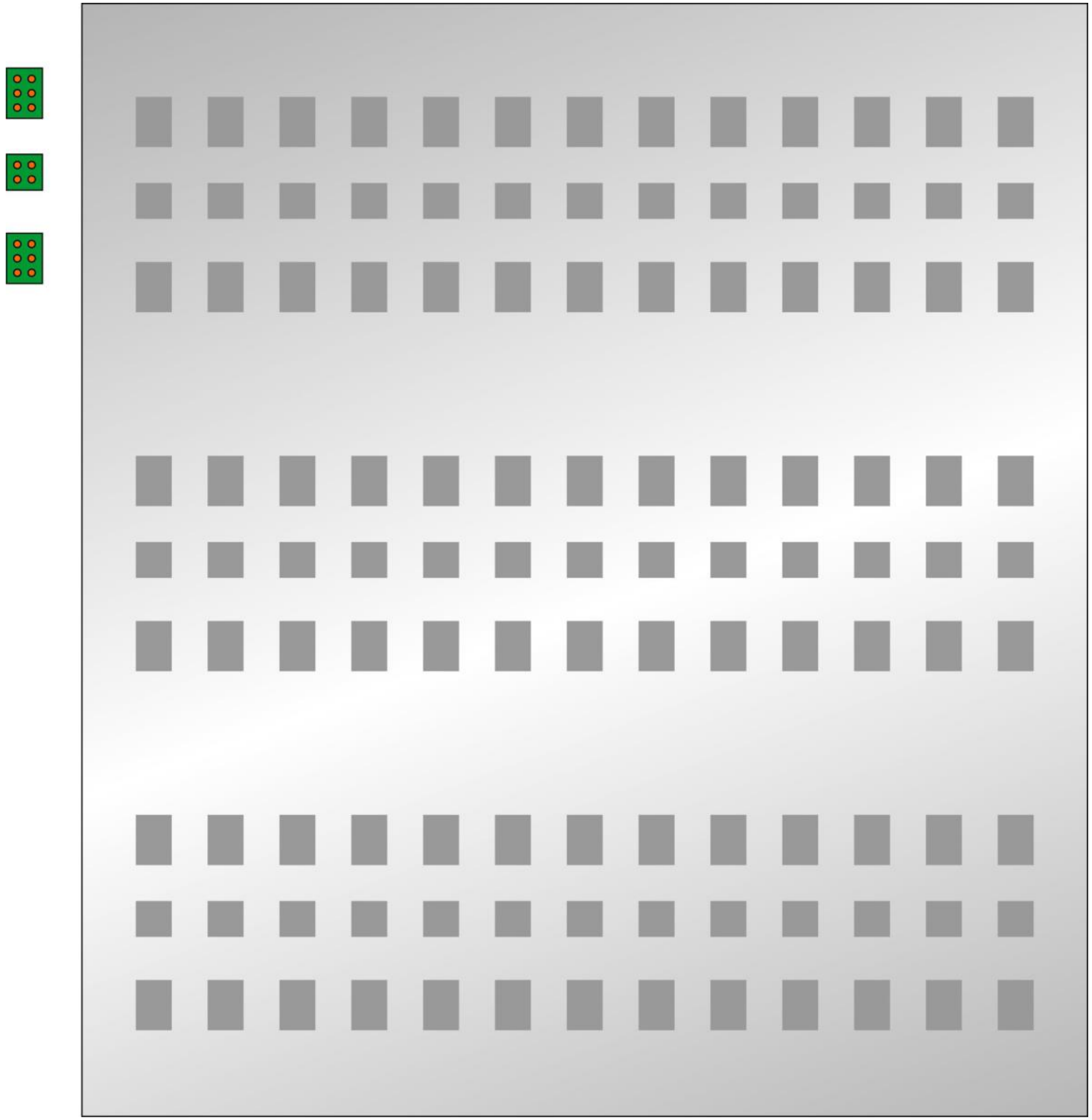


Route Assembly into Discrete Functional Elements (Packages) and Test to Assure Quality

Place Components into Pre-machined Aluminum Carrier

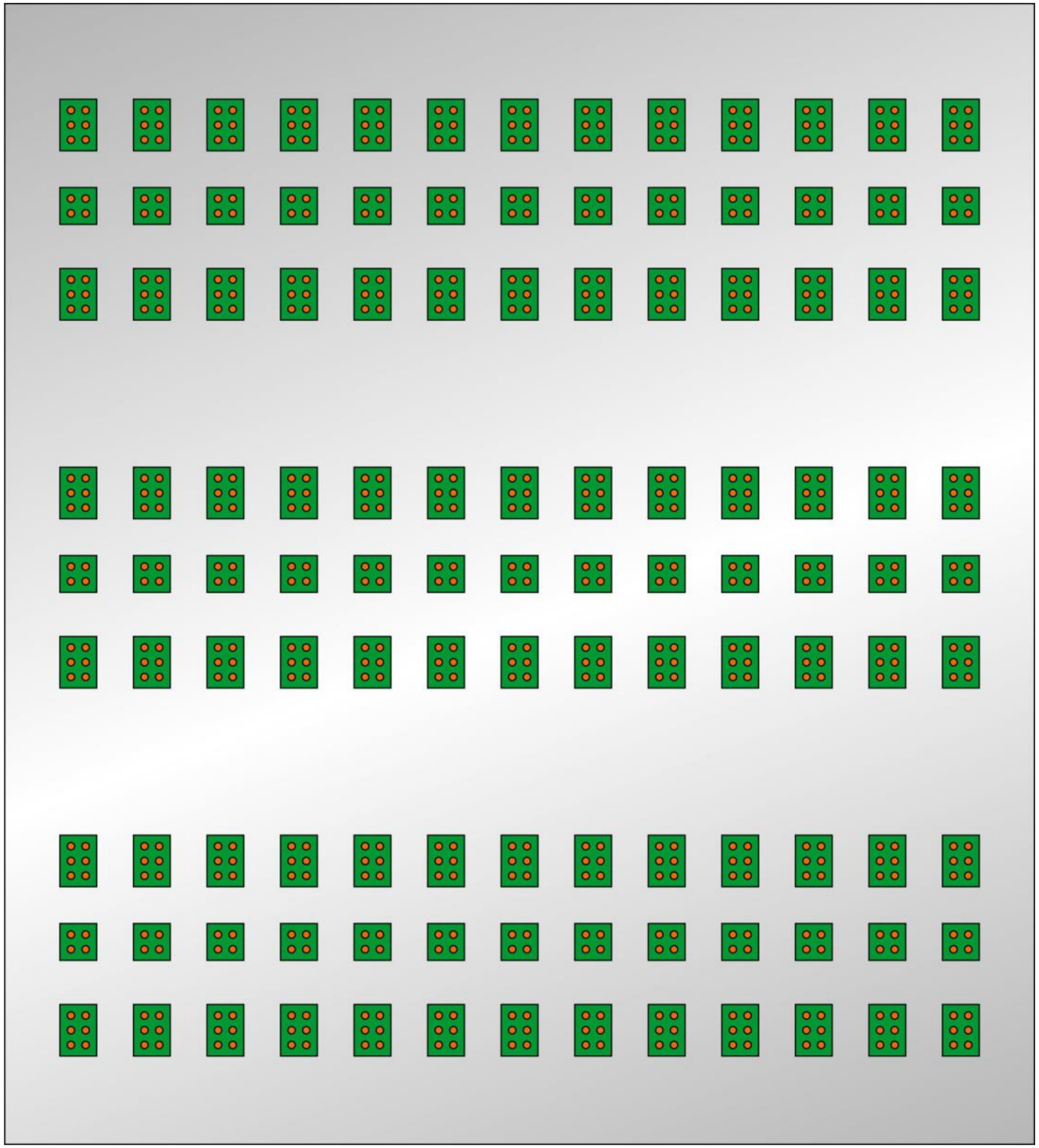


Aluminum Panel and Parts

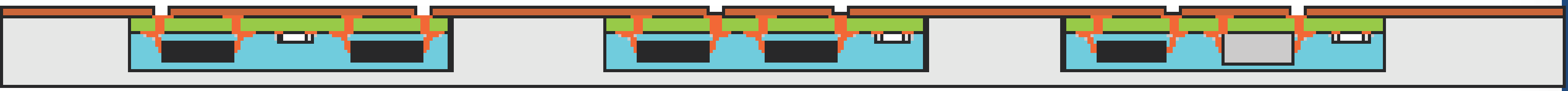


Components When Glued in Place Will Have a Uniform Height

Components Placed



Apply Flexible Film Layer and Create Holes to Access Desired Terminations



Polymer Film Covering

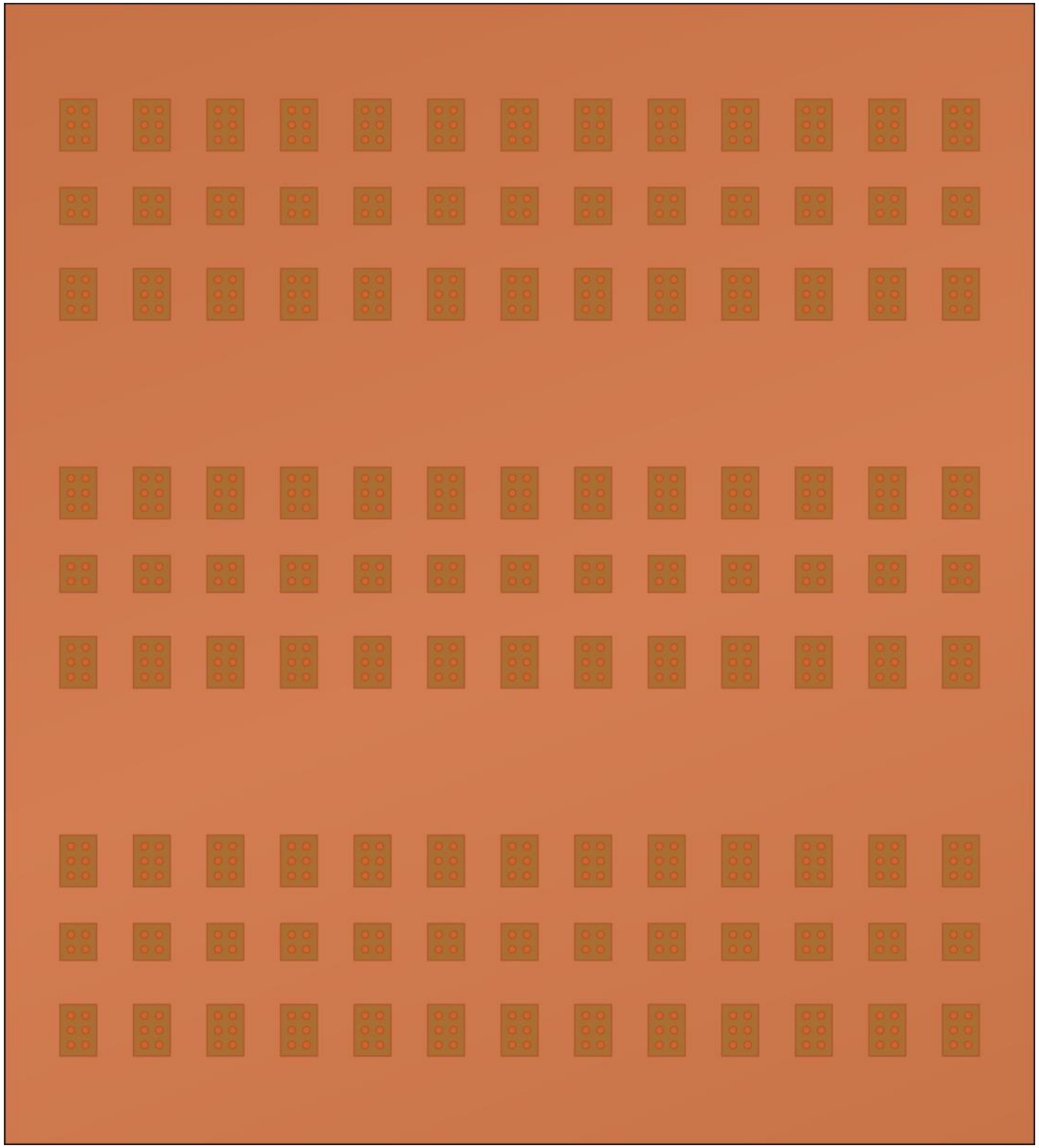
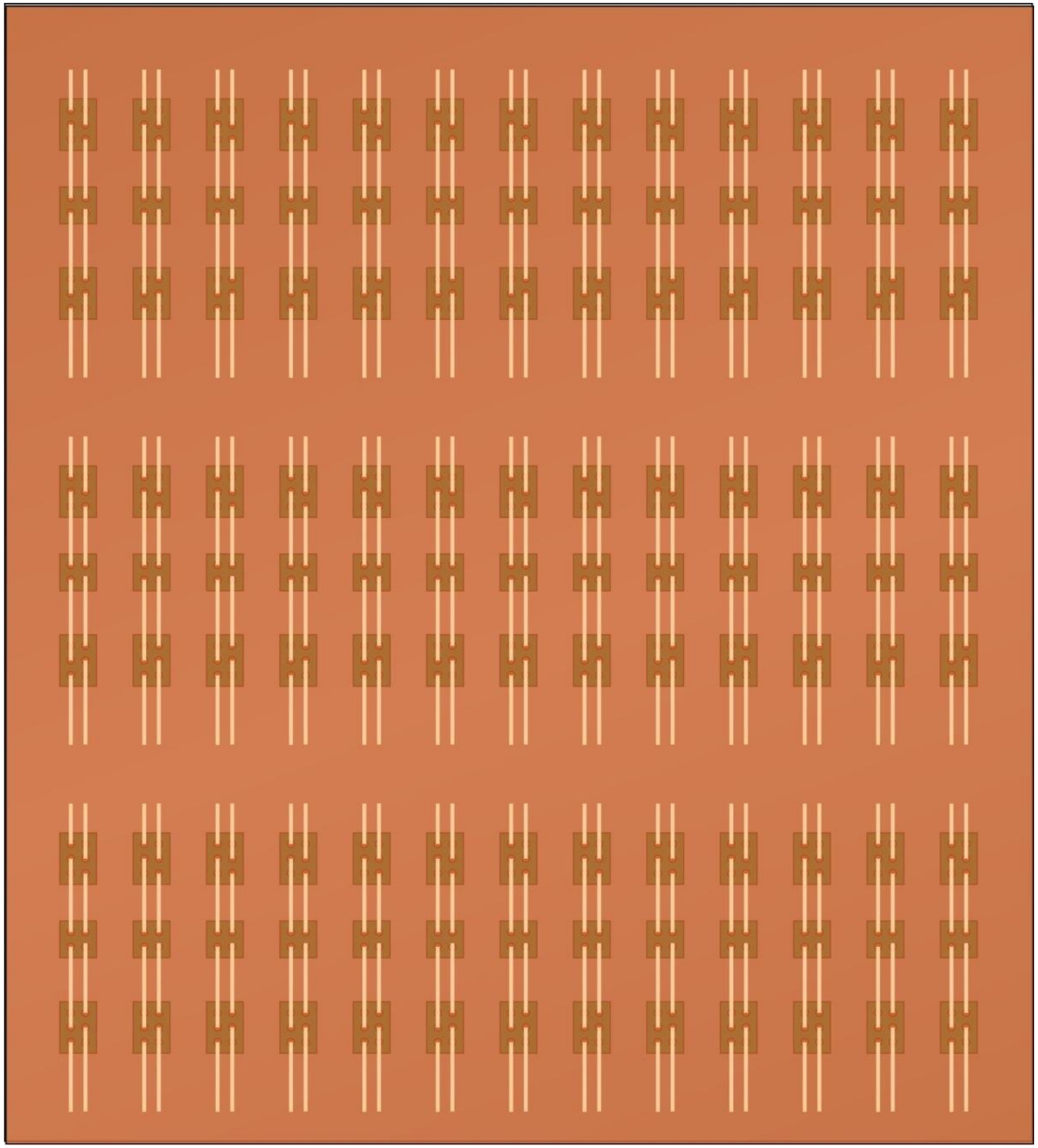
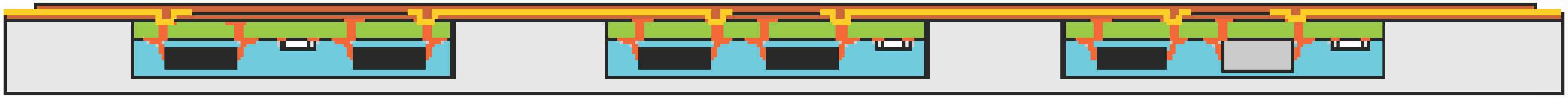


Image and Plate Copper Circuitry Using Microvia Build-up Board Technology

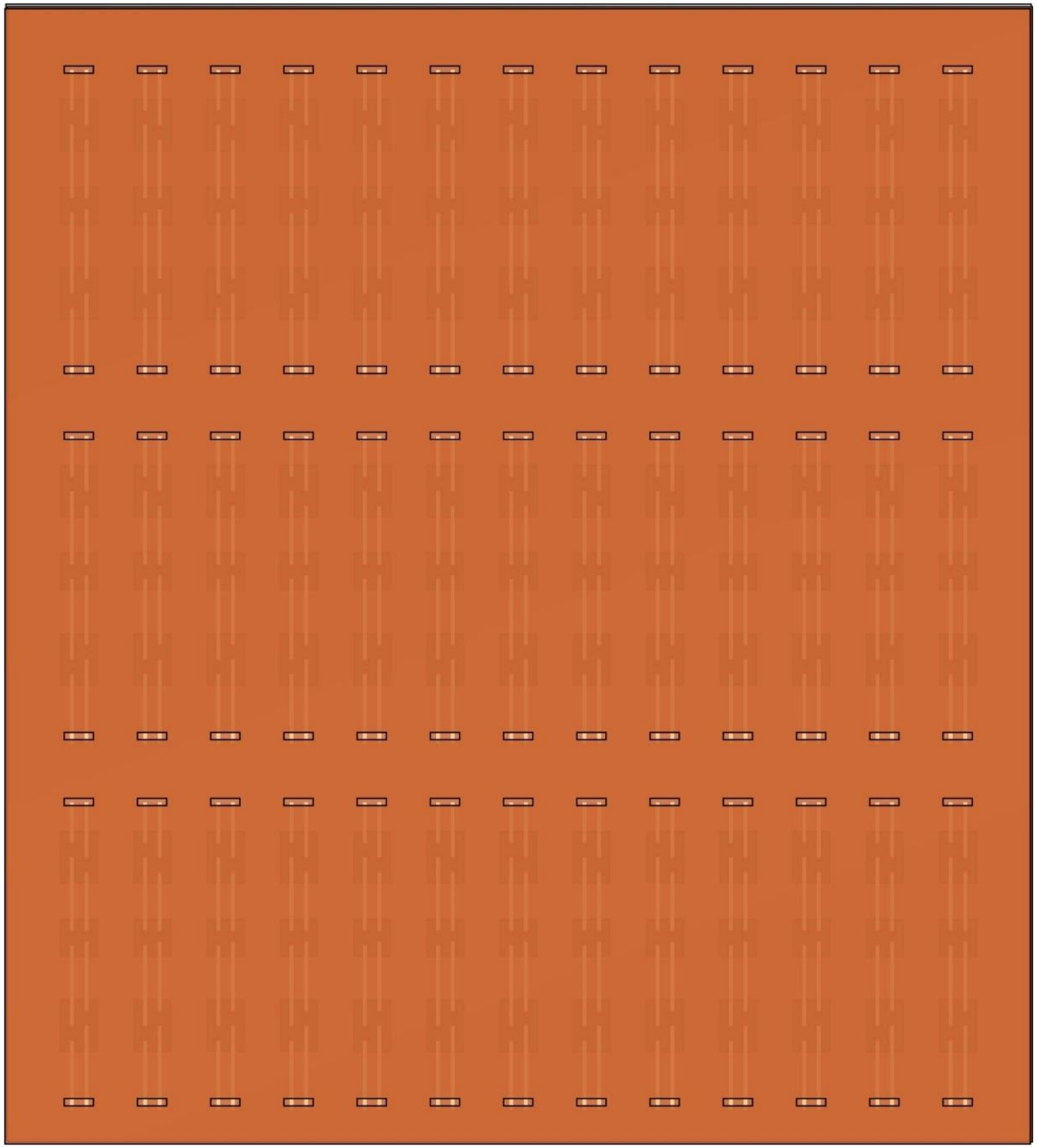
Flex Circuit Processing



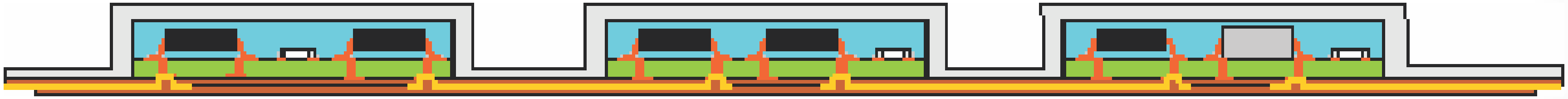
Apply Coverlayer Exposing Terminations of Interest



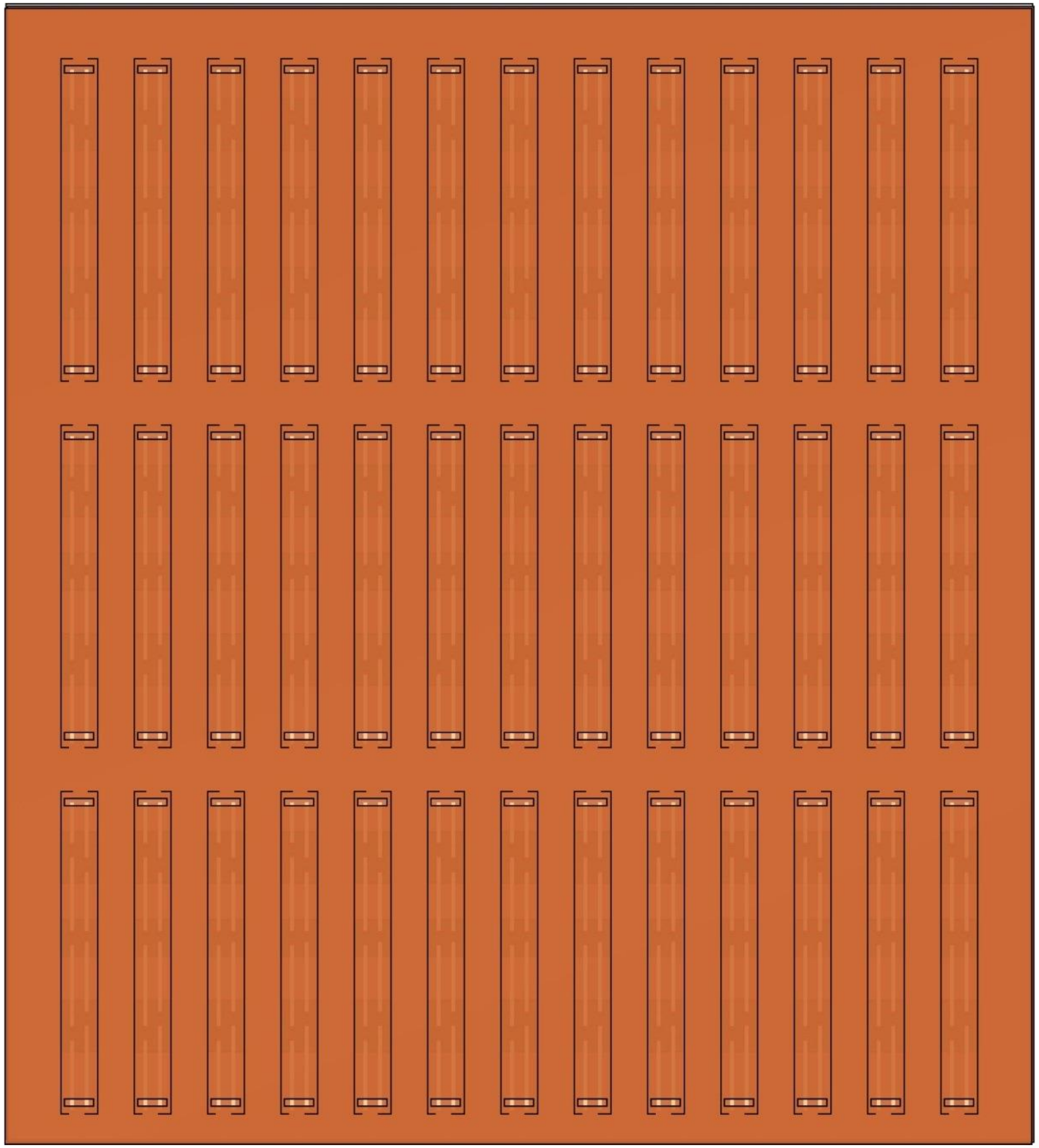
Apply Coverlayer



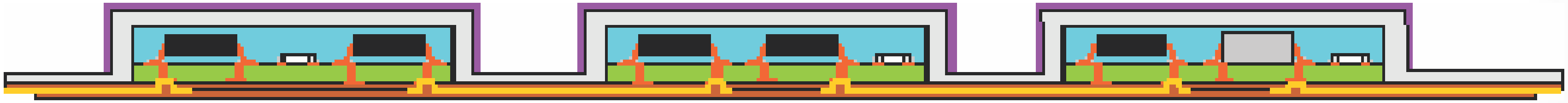
Partially Machine to Thin Areas Where Etching Will Occur



“Kiss cut” with SRD or Laser Skive



Protect Carrier Areas (might be optional if differential etching is used)



Etch Exposed Aluminum

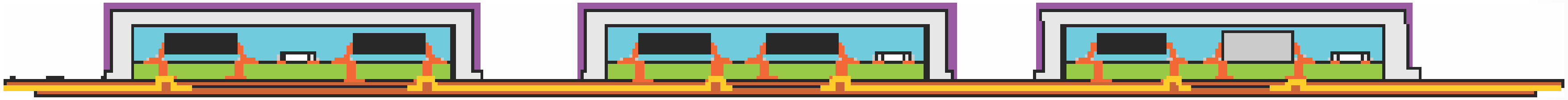
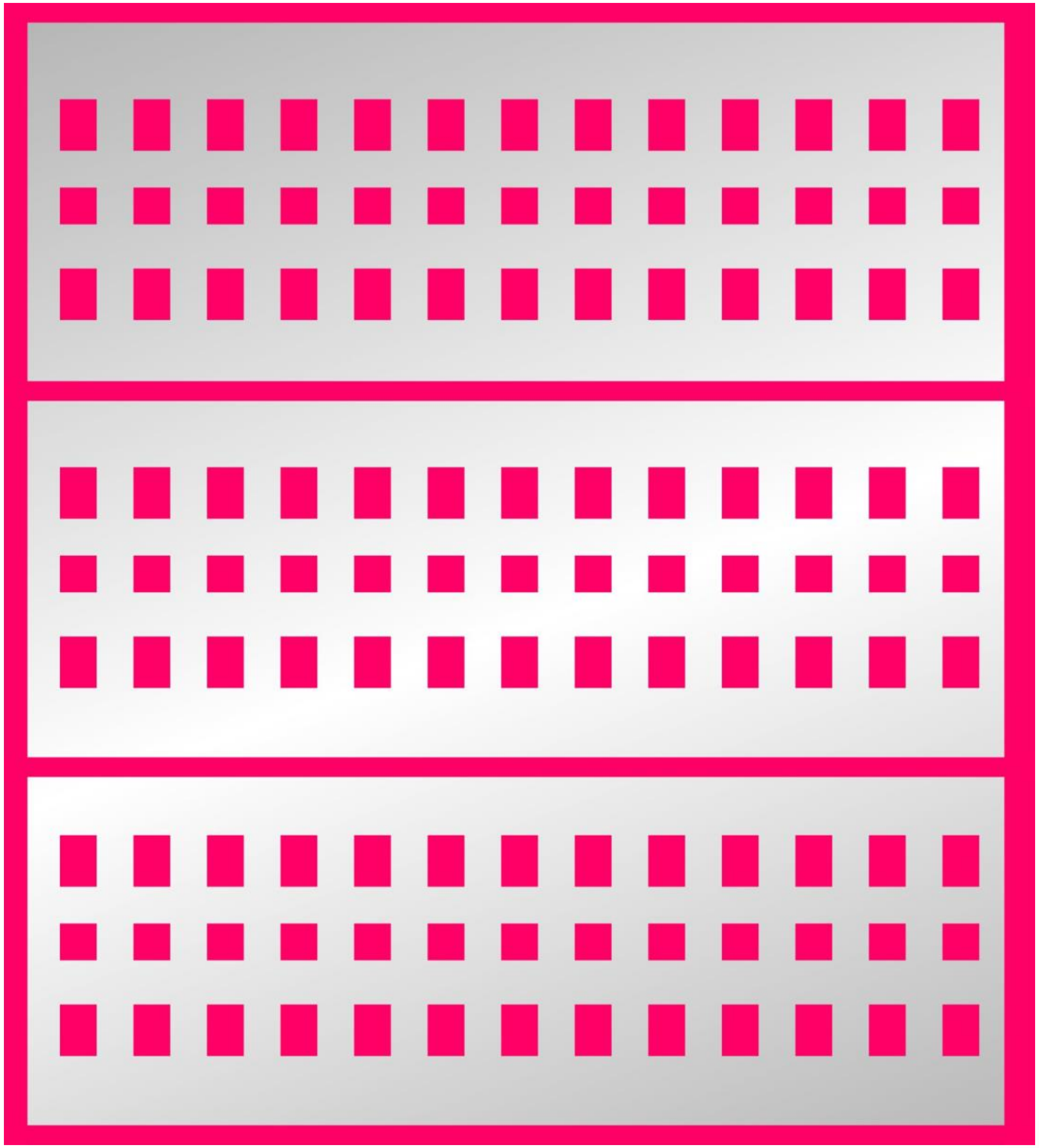
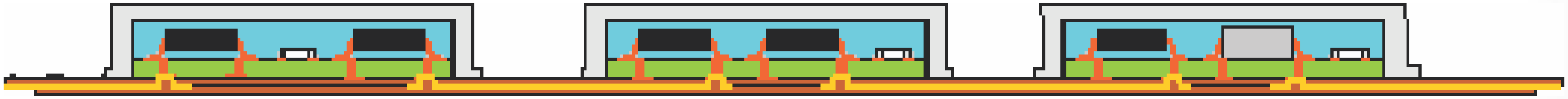


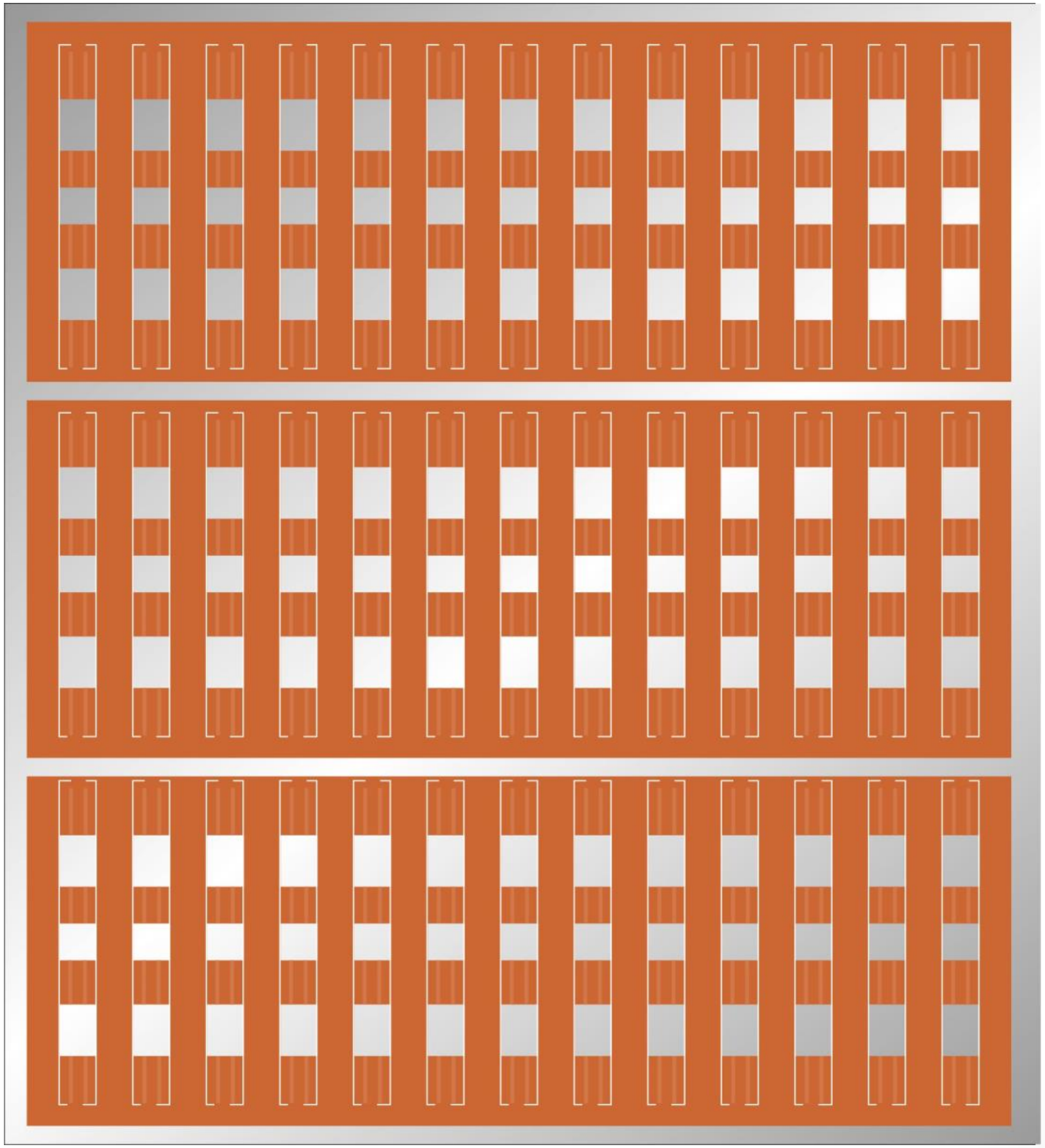
Image to Protect Aluminum



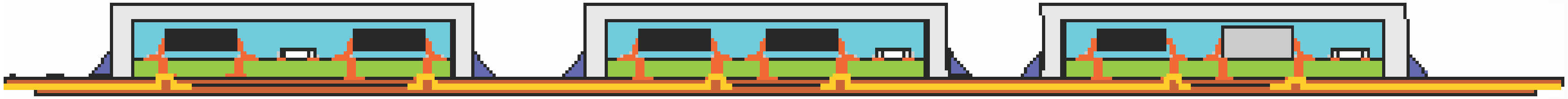
Remove Resist



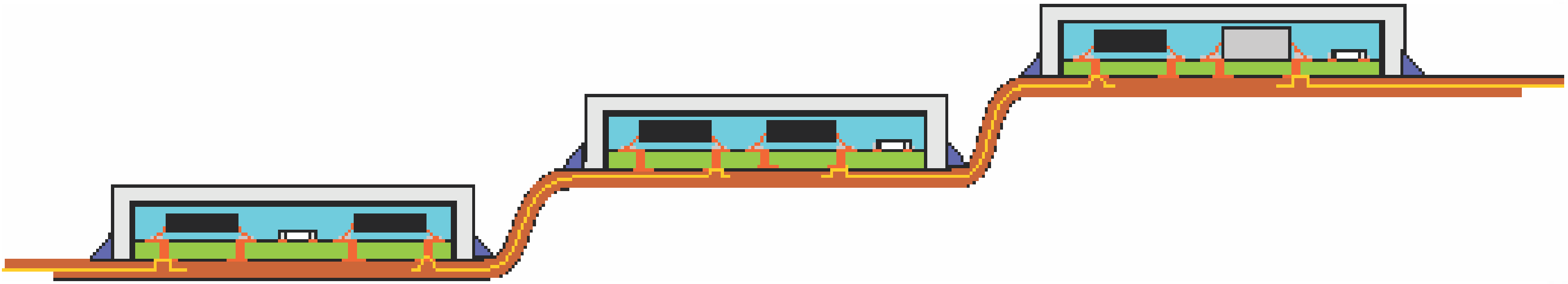
Etch and Remove Resist



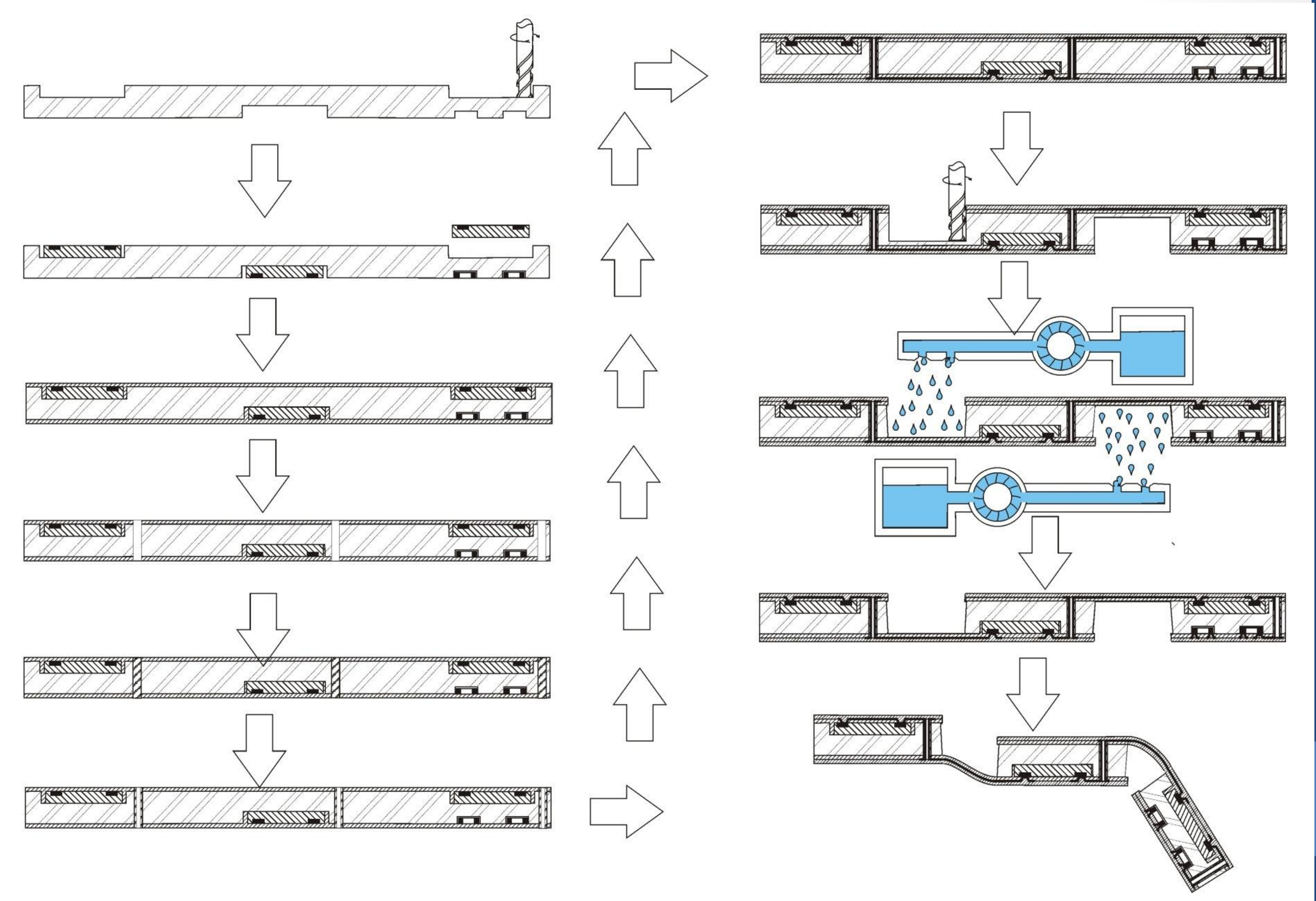
Apply Strain Relief Fillet



Separate and Bend to Shape



Optional Aluminum Core Rigid Flex Process



Summary

- Rigid flex (and flexible) circuit technologies will continue to expand their sphere of influence into new areas of electronic interconnection owing to both their versatility and their intrinsically beneficial mechanical and electrical properties thus opportunities should increase
- Because of the greater levels of engineering required, the cost for more complex structures will be higher but on a system level, the circuits will often prove a more cost effective solution.
- Change is inevitable but adapting to, managing and controlling change is a choice.

Further reading :

- **Flexible Circuit Technology 4th Edition, Joseph Fjelstad**
- (www.FlexibleCircuitTEchnology.com)
- **The Printed Circuit Designer's Guide to Flex and Rigid-Flex Fundamentals, Anaya Vardya and David Lackey**
- http://i007ebooks.com/my-i-connect007/books/printed-circuit-designers-guide-flex-and-rigid-flex-fundamentals/
- **Printed Circuit Handbook 6th Edition Chapter 69 “Multilayer and Rigid Flex Circuits” Joseph Fjelstad**

Mulțumesc foarte mult!