Rigid-flex PCB Design – Practical Tips and Best Practices

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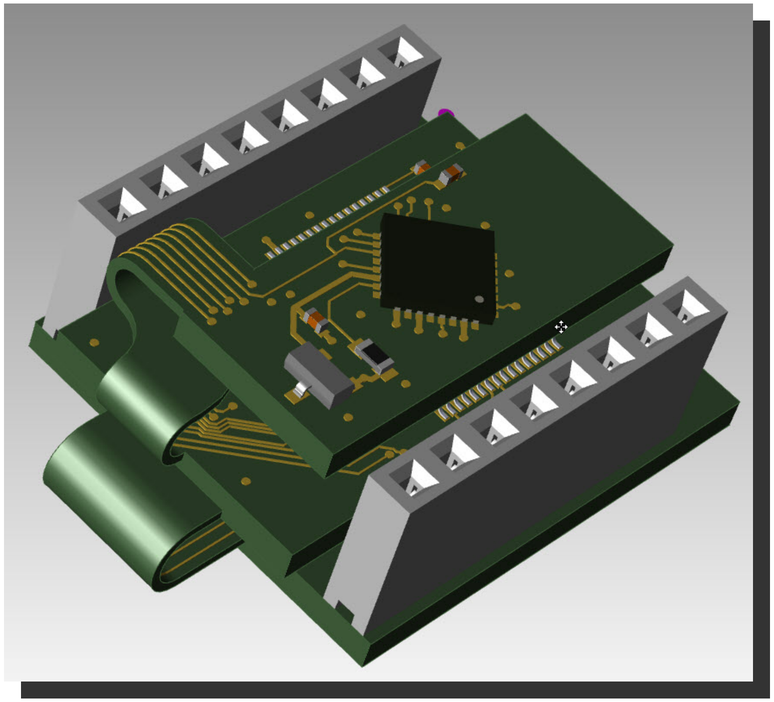
Agenda

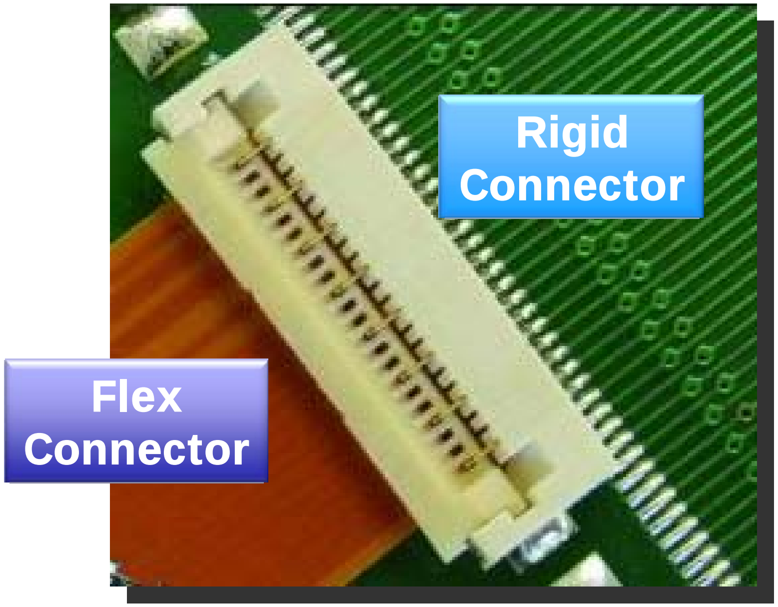
- Brief history – how did we get here and what is rigid-flex?
- Benefits – why use rigid-flex?
- Challenges
- Tips and best practices
  — Includes demonstrations
- Summary



BRIEF HISTORY

History

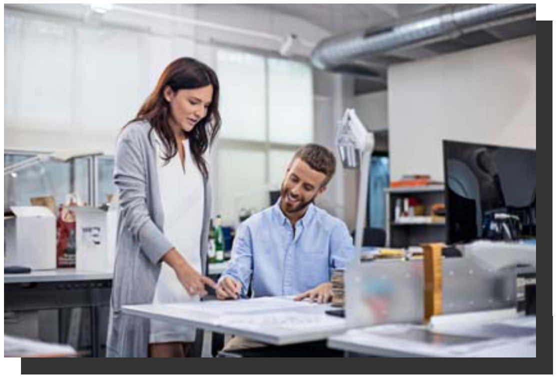
- Prior to the advent of rigid-flex design, when a product required one or more flex PCB(s) the flex and rigid PCB's were designed separately
- Each PCB contained one or more physical connectors
- The individual PCB's were assembled to create the end-product



History

- Flex PCB's – assigned to "flex" designers
- Rigid PCB's – assigned to "conventional" board designers
- This "design-separately-then-assemble" approach minimized potential issues with the flex portion(s) of the product however...

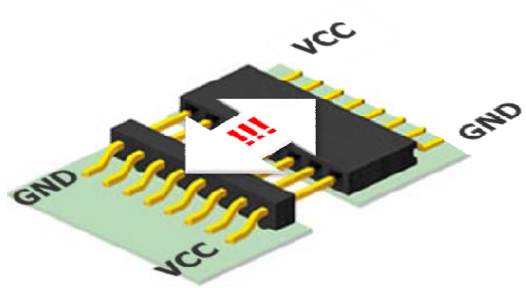
Flex PCB Designers



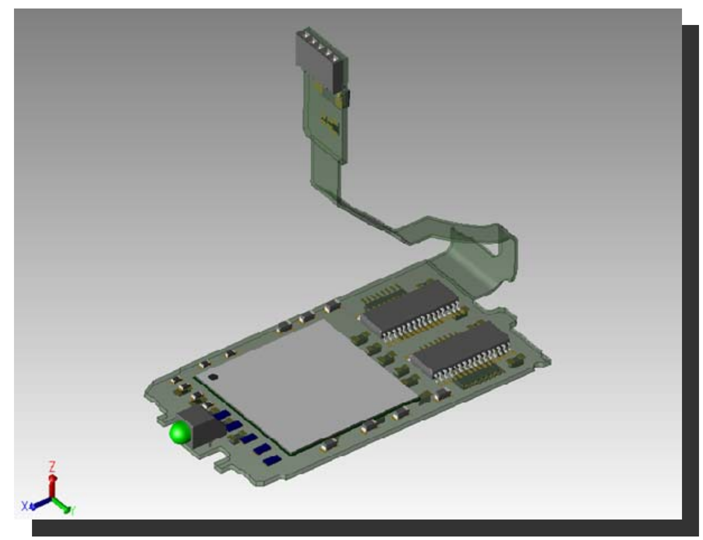
Rigid PCB Designers

History

- Design-separately-then-assemble issues
  - Cost of the connectors
  - Space for the connectors
  - Time and cost associated with assembly
  - Need to properly manage interconnects between the rigid and flex PCB's

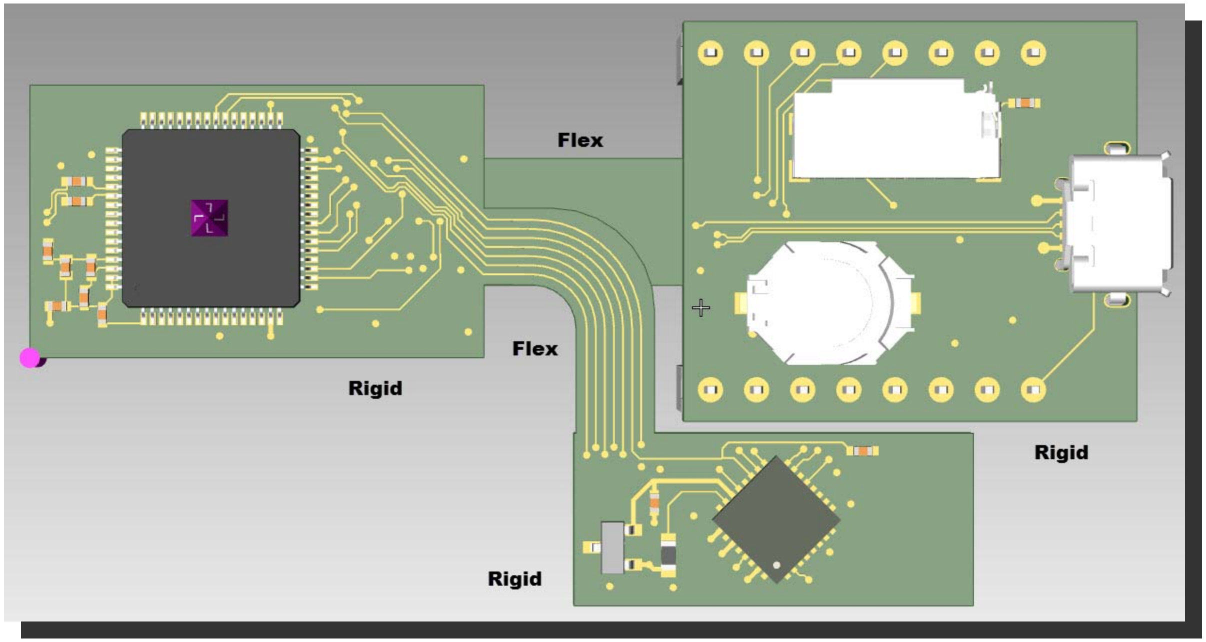


- Design-separately-then-assemble is gradually being replaced with current generation rigid-flex design



Definition

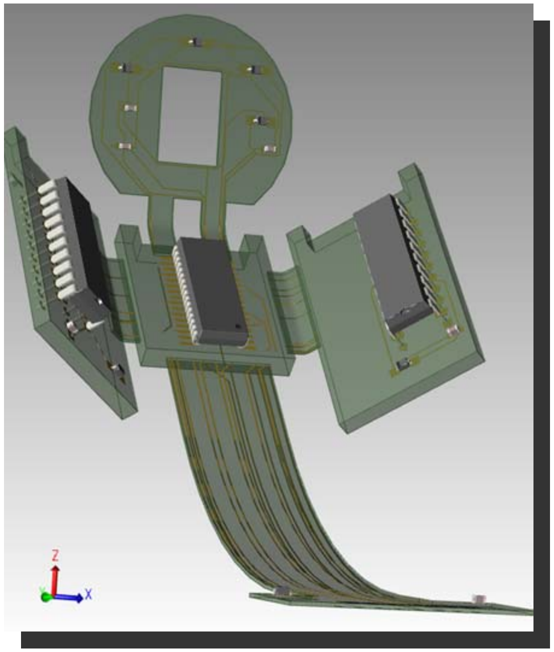
- Rigid-flex - A combination of rigid and flexible board technologies
  - Multiple layers of flexible circuit substrates attached internally and/or externally to one or more rigid boards



BENEFITS

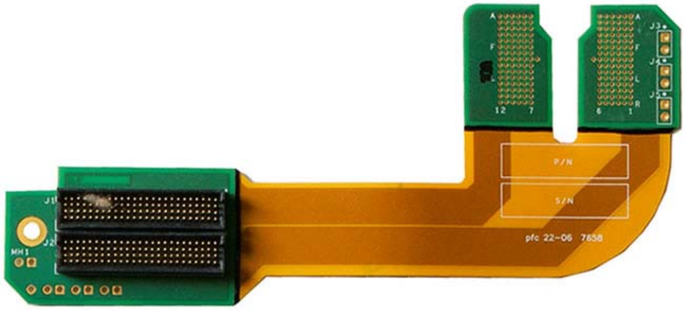
Benefits of Rigid-flex Design

- Provides more options when working with dense designs that must conform to a specific form factor
- Reduces cost and increases reliability through the elimination of physical connectors
- Reduced space requirement as parts can be placed (and traces can be routed) in three dimensions
  — Greater functionality applied to a smaller volume of space



Benefits of Rigid-flex Design

- Improves signal integrity through the elimination of cross-sectional changes to the conductors
  - Removal of physical connectors and their associated solder connections
- Improved electromechanical functionality including dynamic bending, vibration and shock tolerance, heat resistance, and weight reduction
  - Provides the mechanical stability required by most applications



Benefits of Rigid-flex Design - Summary

- Rigid-flex designs are well suited for compact and/or lightweight and/or flexible designs and products
- Current generation rigid-flex designs are typically found in mobile phones, televisions, digital cameras, laptops and **wearables**

Courtesy of Nike

Courtesy of Olympus

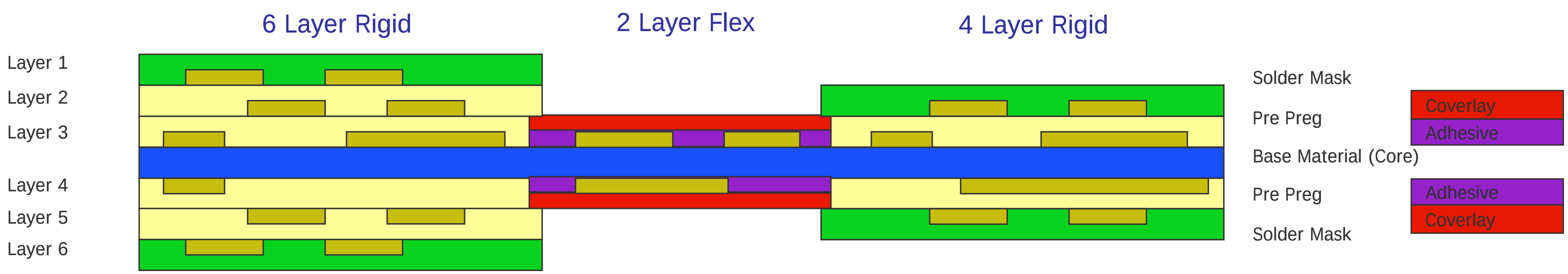
Whenever a product needs to be compact and/or lightweight and/or flexible, rigid-flex technology will most likely be applied

CHALLENGES

Rigid-flex Design Challenges

Stackup management

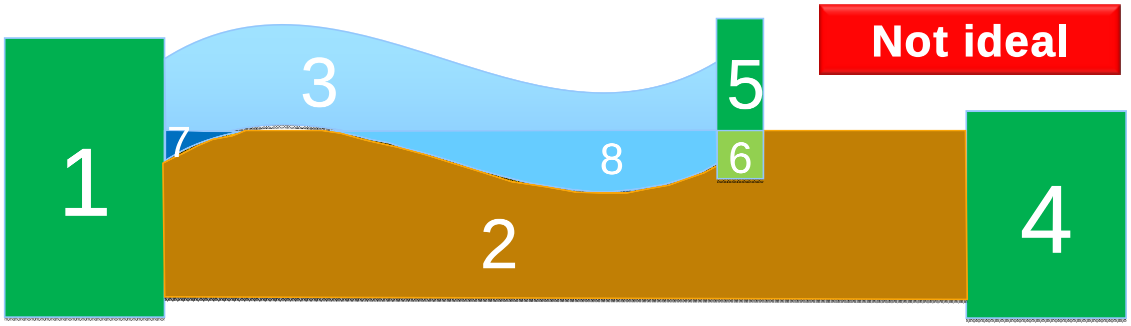
- The stackups for the rigid and flex PCB's will always vary
- Stackups need to be efficiently managed and properly conveyed to the fabricator
- An ECAD tool that supports region-specific stackups (not ideal) or board-specific stackups (preferred) will help simplify this task



Rigid-flex Design Challenges

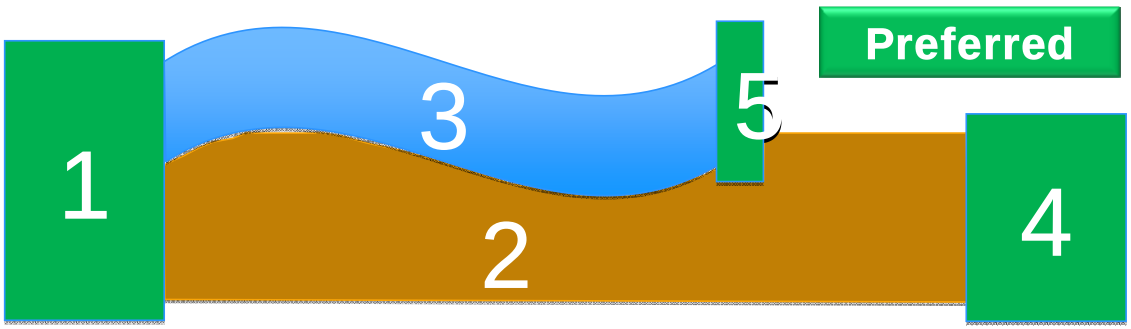
Region-specific stackups

- 8 stackups
- Changing the curved flex requires changing 6 stackup regions



Board-specific stackups

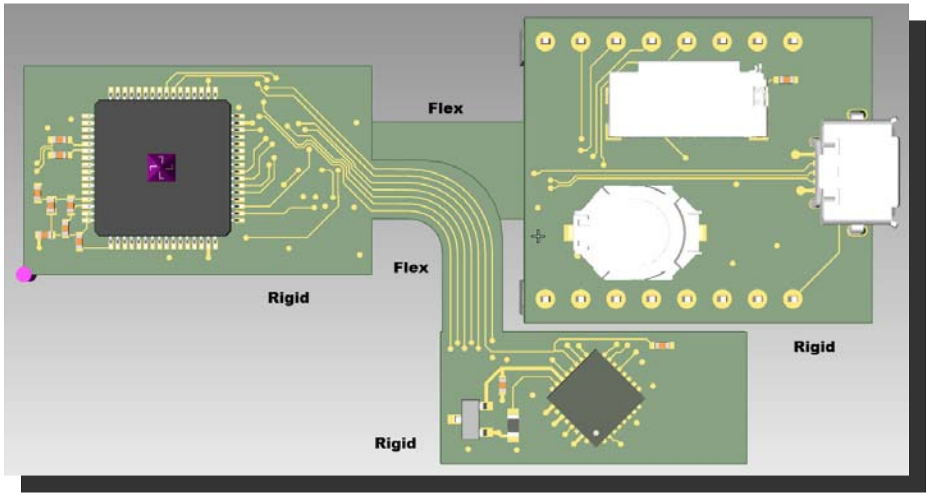
- 5 stackups
- Changing the curved flex is simply a board outline change



Rigid-flex Design Challenges

Board outline management

- The multiple boards in a rigid-flex design need to be properly configured and managed
- Rigid-flex designs are electromechanical in nature and as such can benefit from ECAD/MCAD co-design
- Import and automatic creation of multiple complex board outlines from MCAD will save time and reduce errors
  - DXF import
  - IDX mechanical integration



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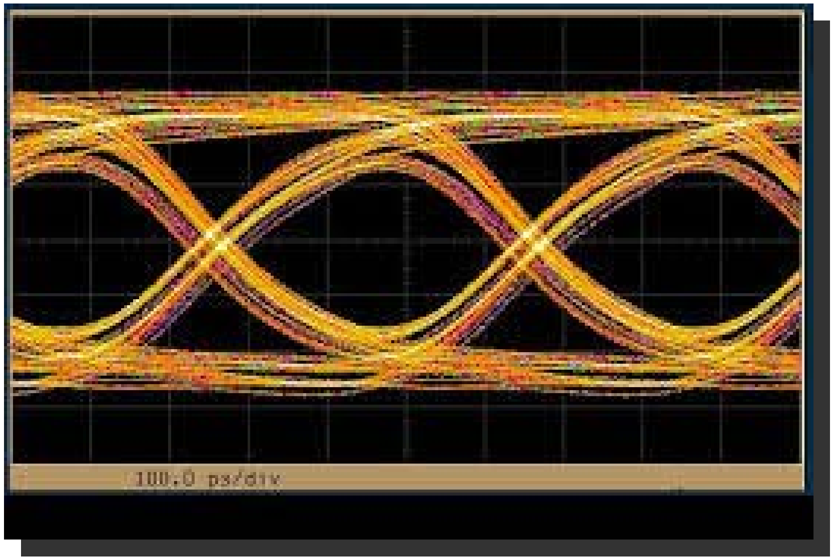
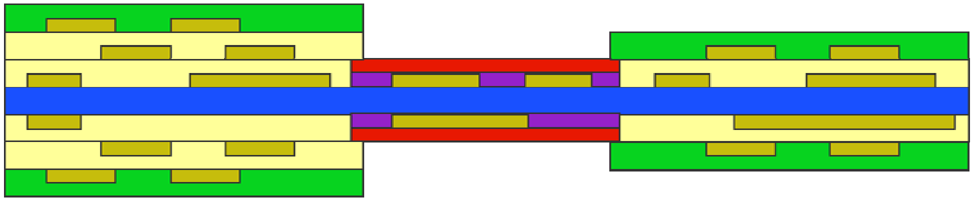
Rigid-flex Design Challenges

Signal and power integrity analysis

- Most signal integrity and power integrity tools assume a single PCB with a uniform stackup
- For rigid-flex designs the ECAD simulation tool(s) must recognize flex-specific layers and local stackups in order to ensure correct analysis results





6 Layer Rigid 2 Layer Flex 4 Layer Rigid

Rigid-flex Design Challenges

Bend area management

- Rigid-flex designs will have one or more bendable regions
- The ECAD tool must be able to:
  - Define the bend location
  - Define how the bend is applied (radius, angle, origin, etc.)
  - Define bend-specific rules for placement, routing, vias and planes
- Bend area(s) must be properly interpreted during **design**, **visualization** and **verification**

Type

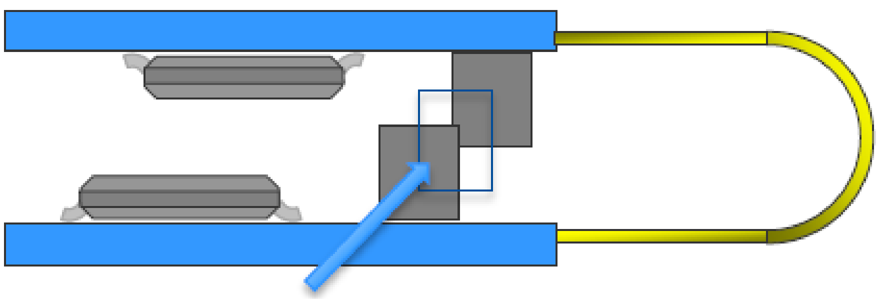
Bend Area

Board Outline	Flex_Connector
Bend Radius (mm)	150
Bend Angle	90
Bend Origin	Center
Bend Order	1
Area Tolerance (mm)	0
First Corner (mm)	0
Dynamic Bend	
Allow Corners	
Allow Width Changes	
Allow Non-Perpendi...	
Allow Vias	
Allow Solid Fill	
Allow Parts	
Left Slide Distance	0
Right Slide Distance	0
Binding Length	0

Rigid-flex Design Challenges

Design, visualization and verification

- An ECAD tool that supports **3D** design, visualization and verification ensures proper utilization of all available space
  - Place and route in 3D
  - View the design in its bent state and in the context of the enclosure in 3D
  - Perform 3D rigid-flex aware design rule checks (DRC)
- 3D design, visualization and verification can identify potential issues early, prior to fabrication and assembly



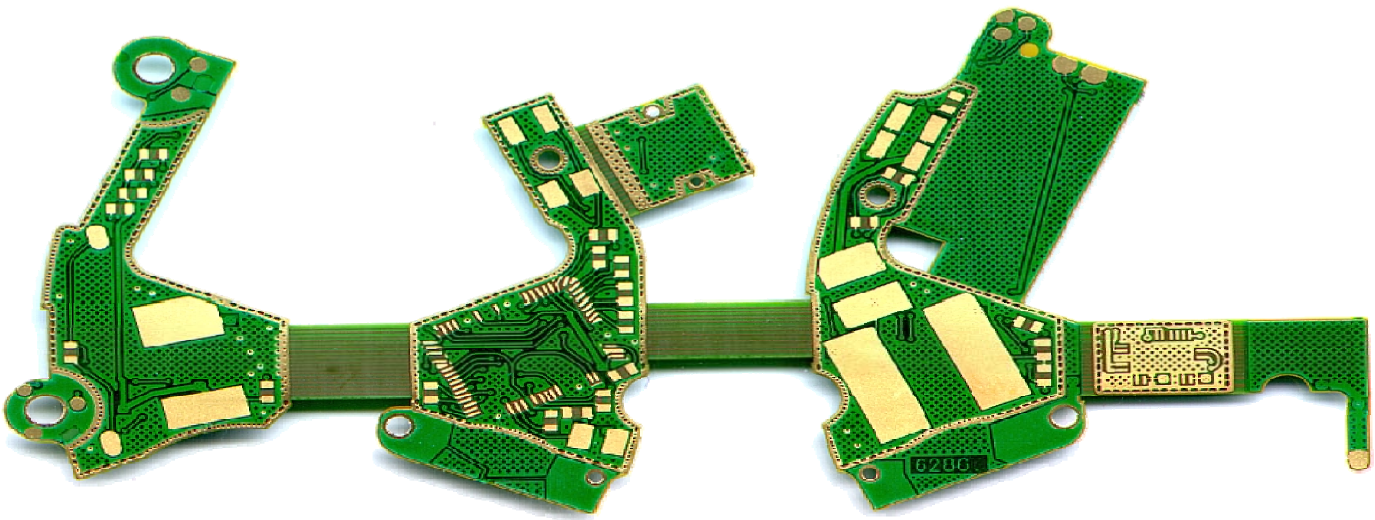
Violation Detected

TIPS AND BEST PRACTICES

Tips and Best Practices

- Tips and best practices focus on three (3) critical areas

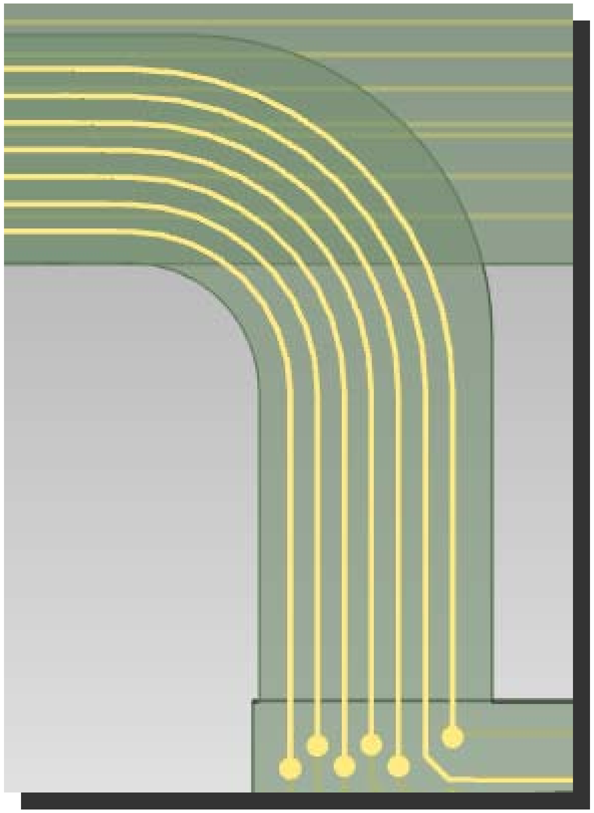
1. Flex design
2. Flex bend region design
3. Fabricator interaction



Flex Design – Best Practices

Traces

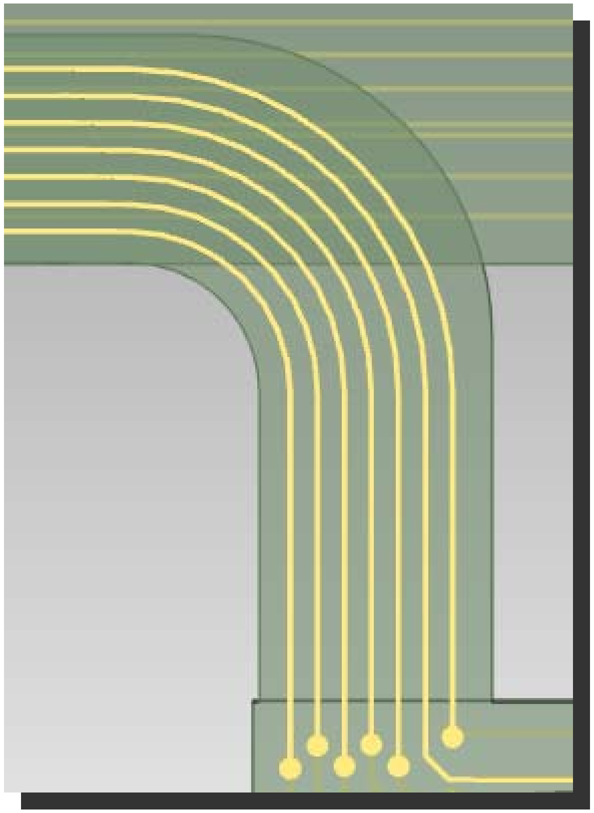
- Trace width and spacing should both be as large as possible
- 90 degree corners should be avoided
- Traces should use round corners
- Round corners must be true arcs
  - — Segmented arcs will create stress fractures



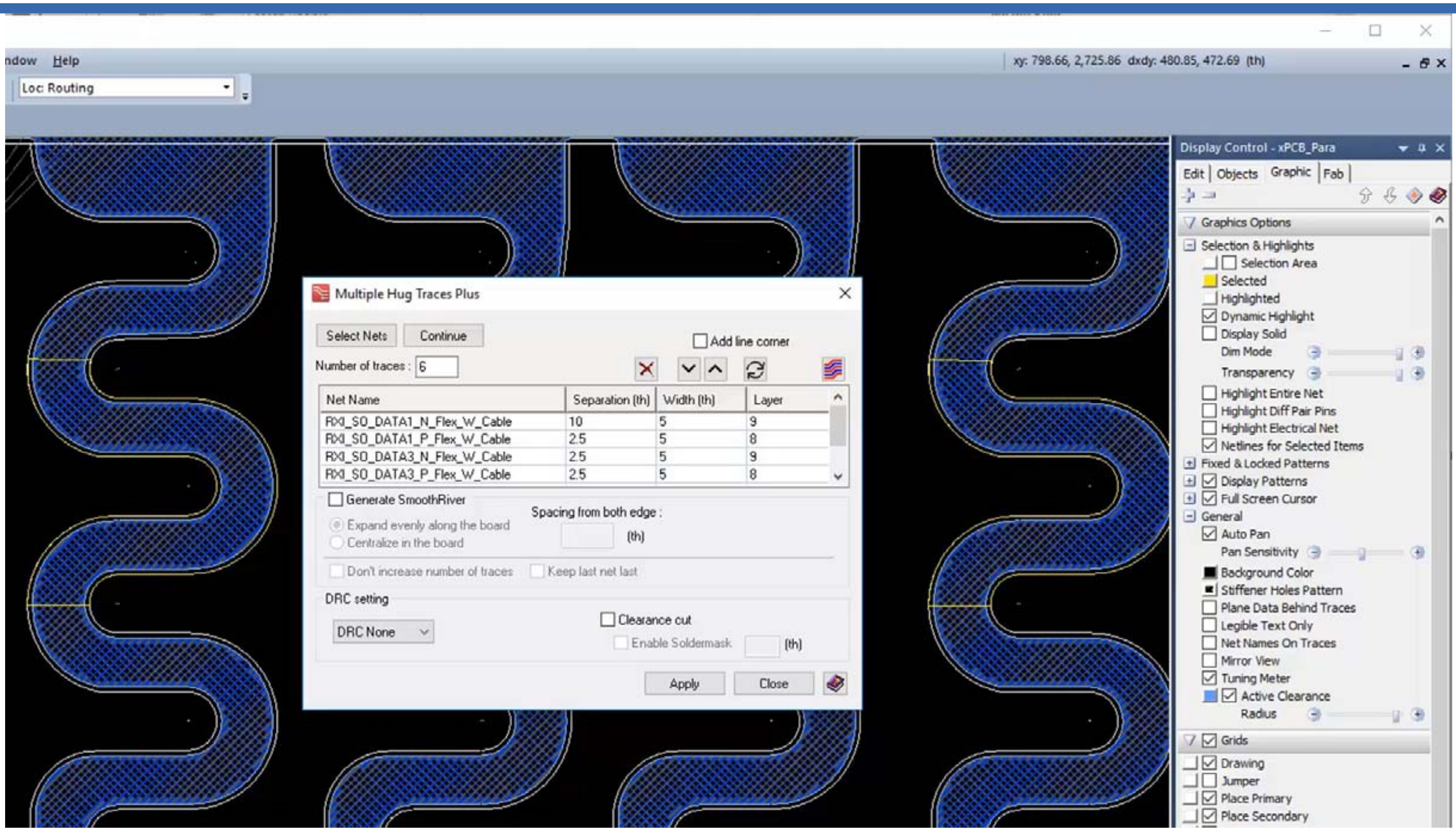
Flex Design – Best Practices

Traces

- The trace contour should mimic the flex board outline contour
- An ECAD tool that allows the trace routing to automatically follow the board outline contour will help save time
- If there is a need to route on more than one layer, stagger the traces for adjacent conductors



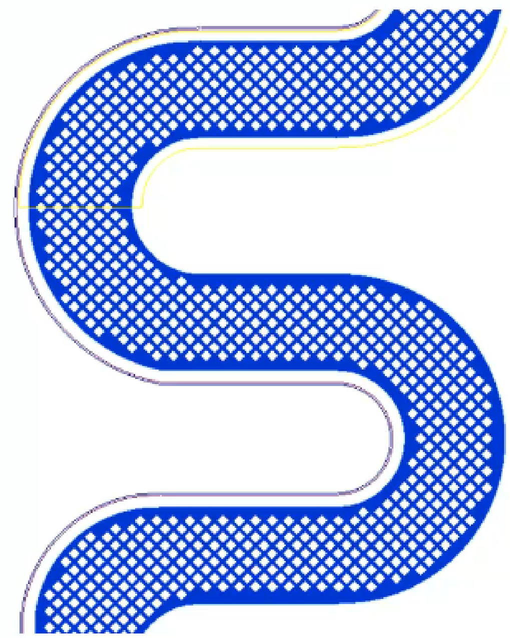
Demonstration –
Contour Routing with Staggered Traces



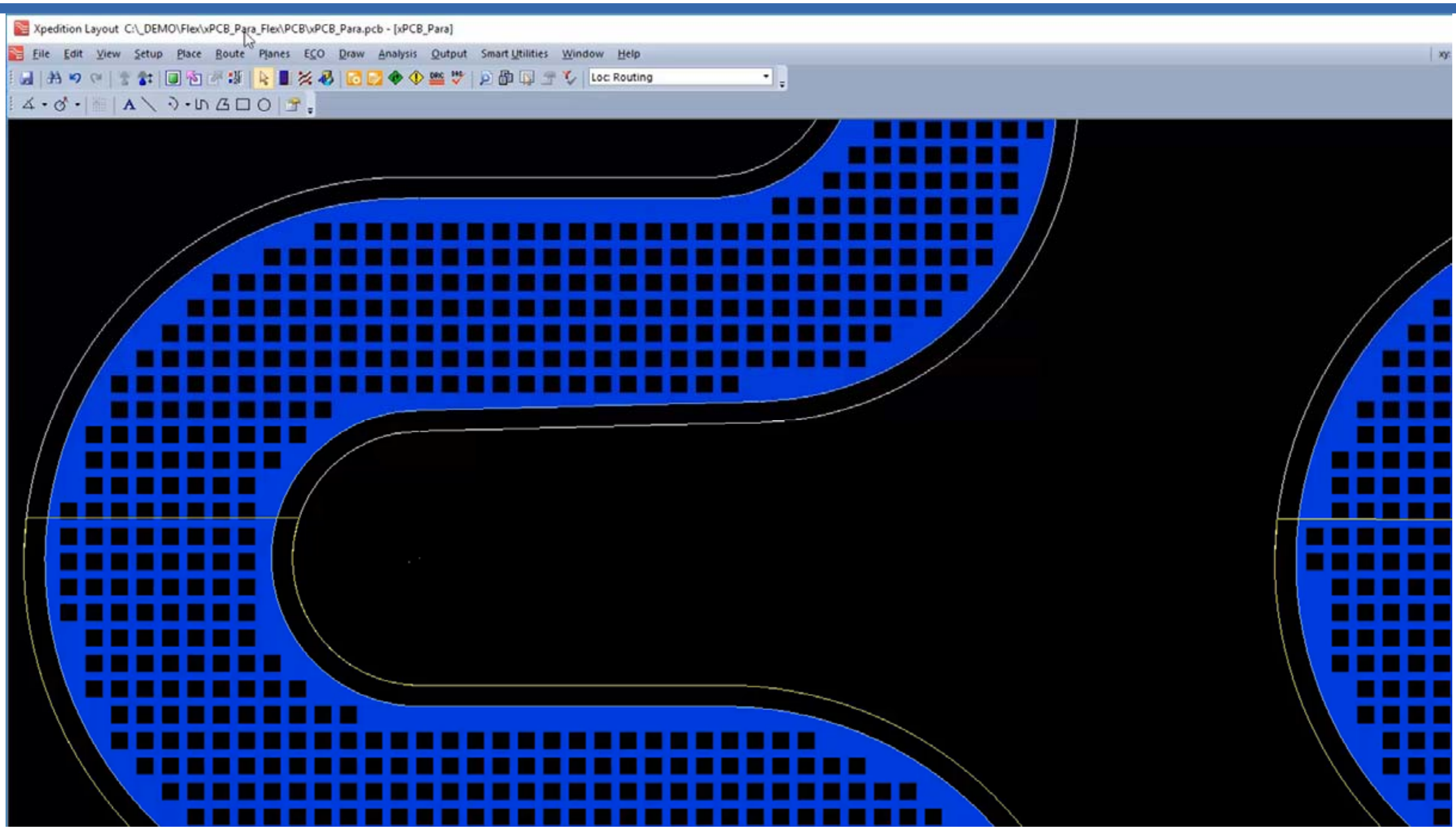
Flex Design – Best Practices

Planes

- Cross-hatch power/ground planes as permitted by electrical requirements
  - Reduces weight
  - Improves flexibility
  - Assists with EMI shielding
- Reminder: Cross-hatching a plane has an impact on the impedance of any conductor using it as a return path



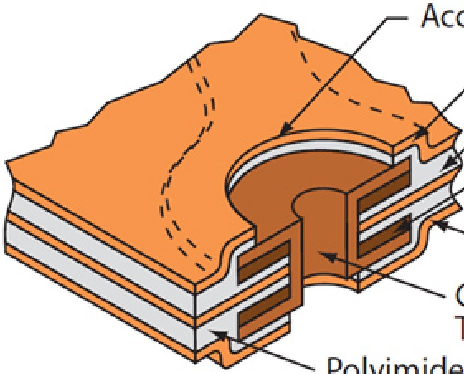
Demonstration – Planes



Flex Design – Best Practices

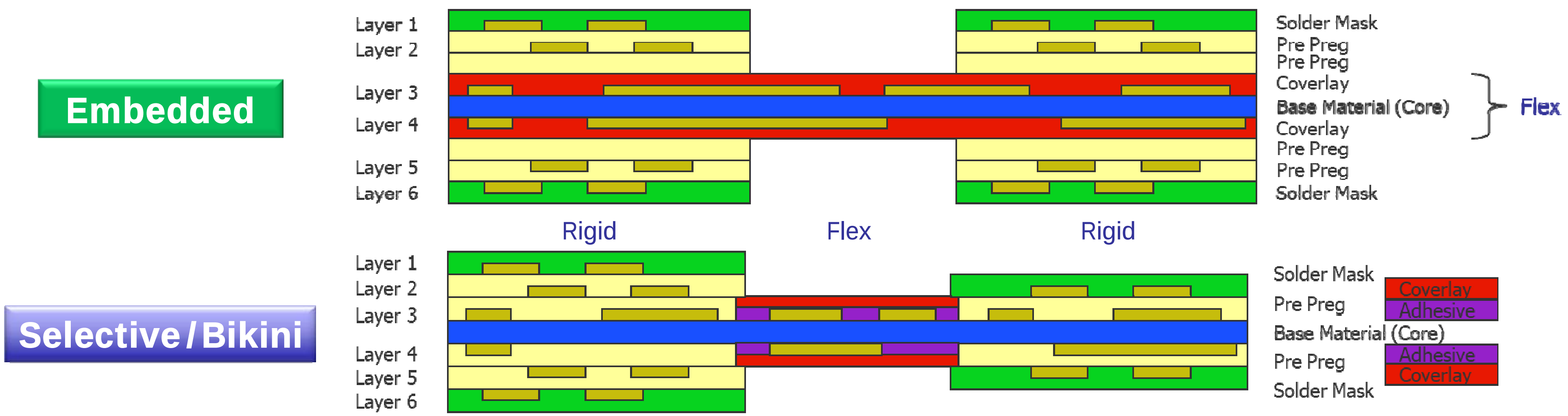
Cover layers

- Insulating layers
- Protects traces from shorting to conductive surfaces
- Greater flexibility and durability as compared to solder mask
- Wide variety of materials available
- Cover layers can extend completely through the entire circuit (embedded) or just over the flex portion (selective/bikini)



Flex Design – Best Practices

Cover layers

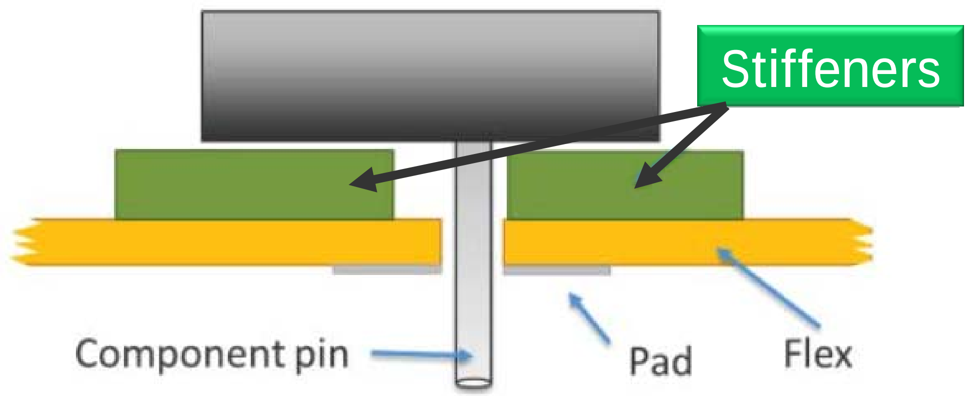


- ECAD tool should support cover layer and adhesive layer within the stack-up definition

Flex Design – Best Practices

Stiffeners

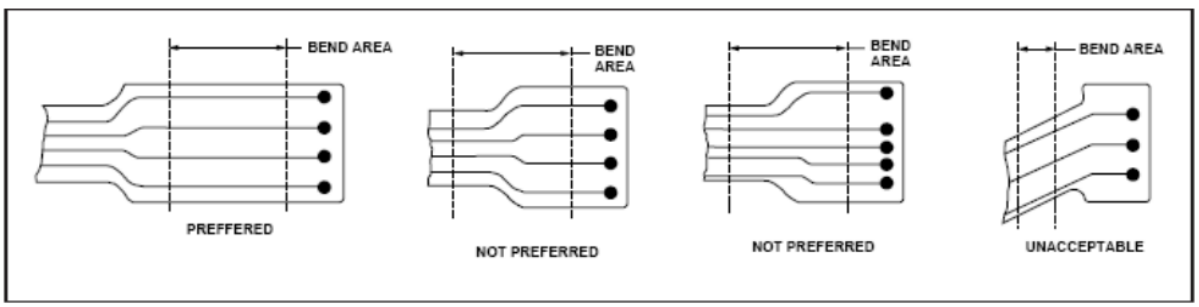
- Rigid material bonded to flex to “rigidize” a section of the flex
- Allows components to be mounted on the flex area
- Used if any portion of any flex requires a part such as a plug, flex connector or jack
- ECAD tool should support stiffeners within the stack-up definition



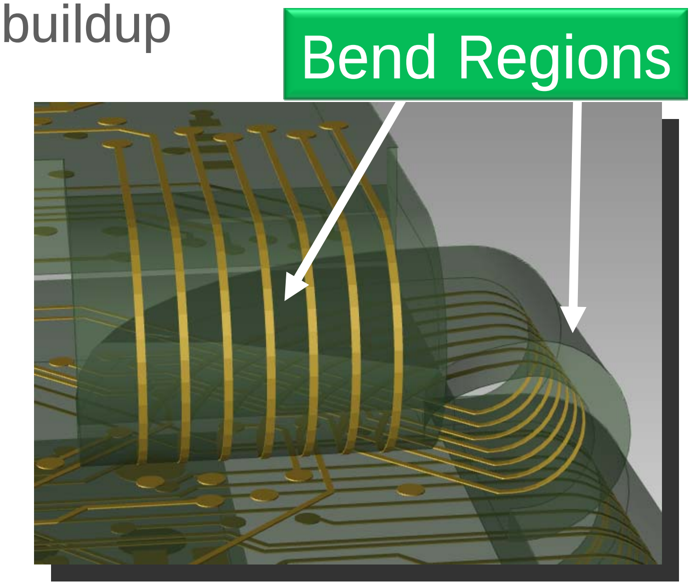
Flex Bend Region Design – Best Practices

Traces and vias

- Do not change the width of the traces within the region
- Route traces perpendicular to the bend direction
  - Lack of symmetry increases the chance of stress buildup
- Distribute traces evenly
- No vias permitted within the region



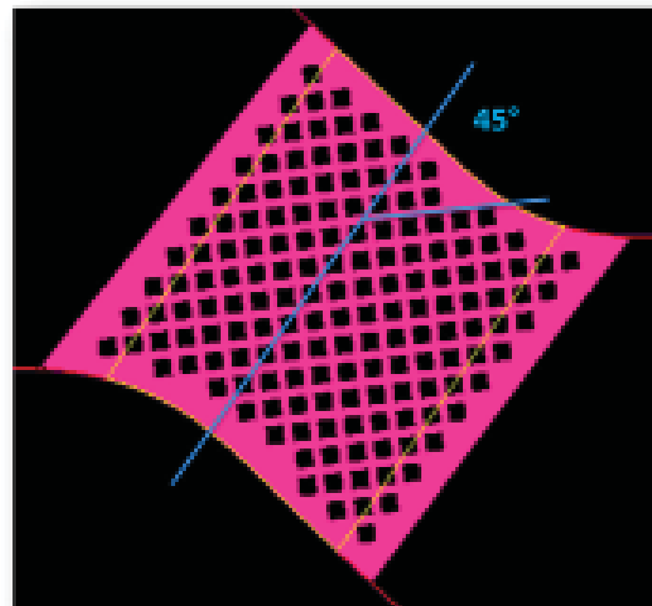
Source: IPC-2223



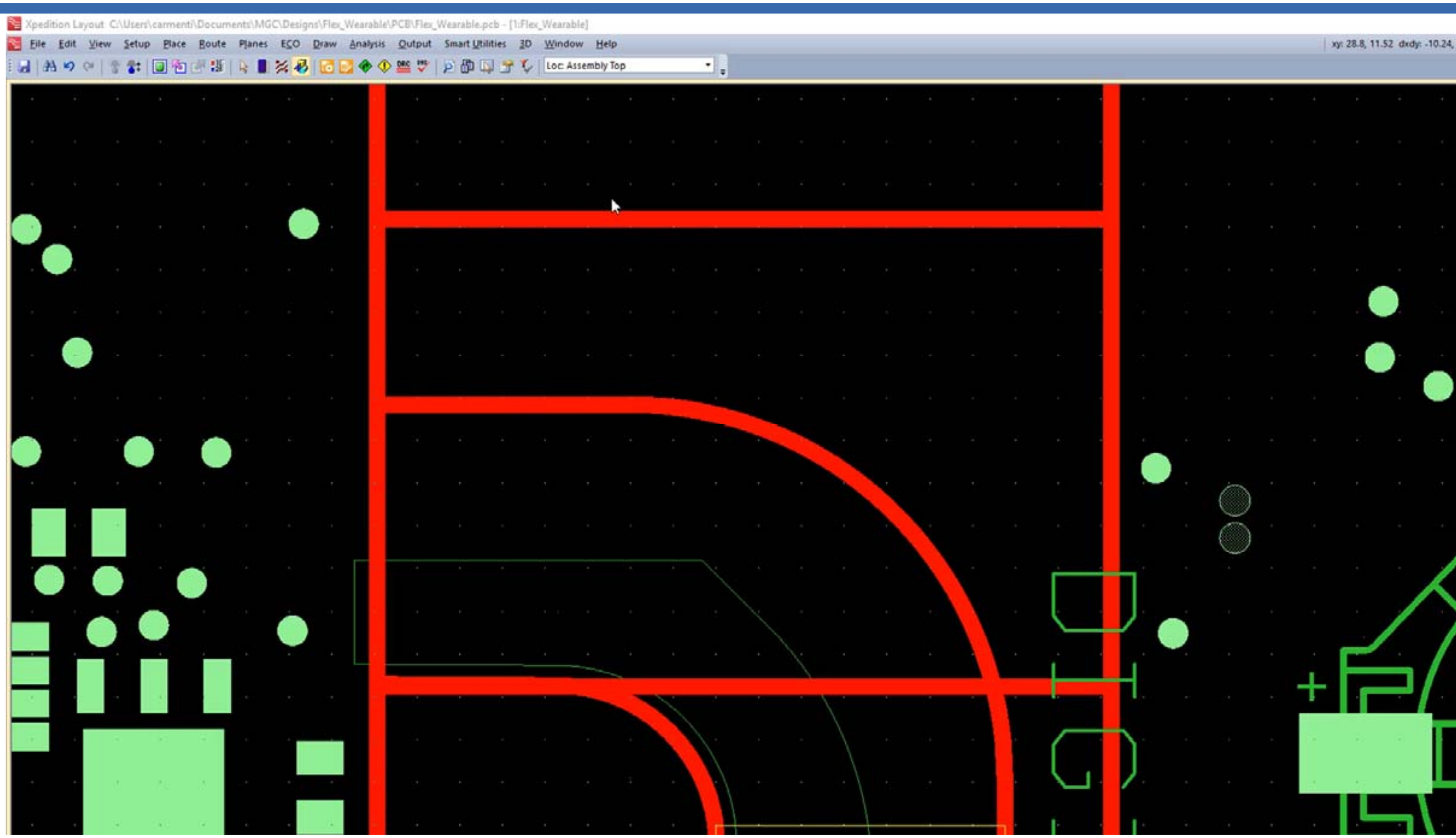
Flex Bend Region Design – Best Practices

Planes

- Hatched planes should be parallel with the bend region
- Cross-hatched planes are preferred
  - Cross-hatch pattern should be at a 45 degree angle in relation to the bend line
- An ECAD tool that can calculate the cross-hatch angle in relation to the bend line will save time and effort
  - Especially for designs with odd angle bend lines



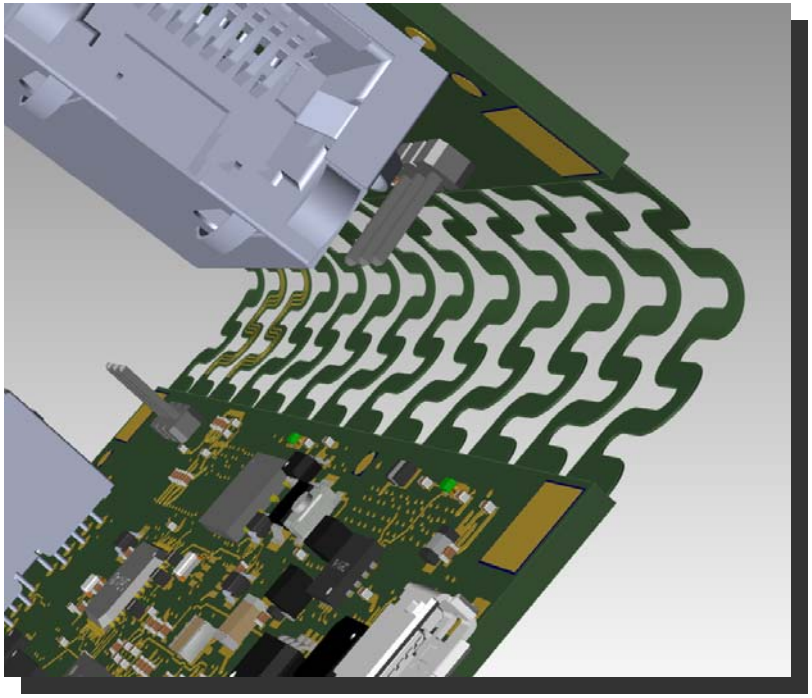
Demonstration – Adding a Flex Bend Region



Flex Bend Region Design – Best Practices

Bend radius

- Bend radius calculation is the greatest challenge associated with the bend region
- Requires close collaboration with the fabricator
- Bend radius is critical in order to avoid compression (area inside of the bend) or tension reliability issues



Flex Bend Region Design – Best Practices

Bend radius

- Requirements will vary based on the application
  - One time crease
  - Flex-to-install aka Static
  - Dynamic

Example:

50 µm [1,969 µin] dielectric, 25 µm [984 µin] adhesive, 35 µm [1,378 µin] copper

Therefore, D = 75 µm [2,953 µin], C = 35 µm [1,378 µin]

Total thickness of flexible circuit T = 185 µm [7,283 µin]

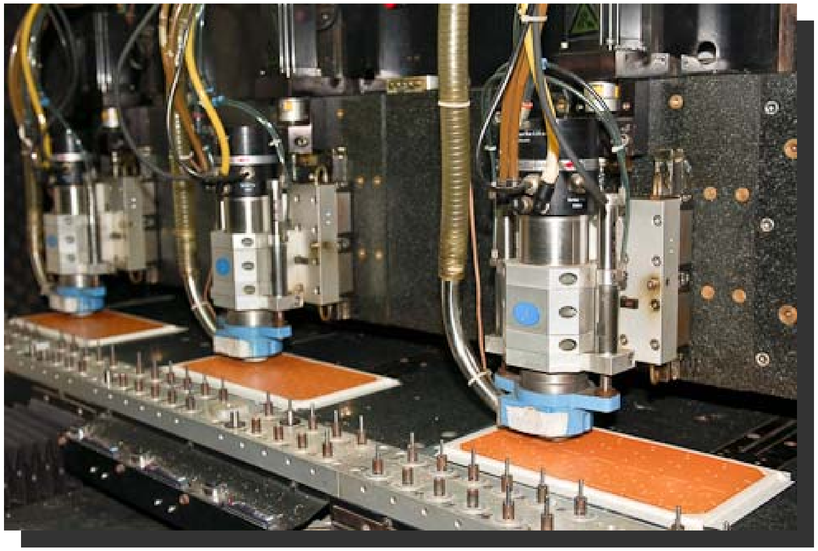
One time crease, use 16%	R = 16.9 µm [665 µin], or a R/T = 0.09
Flex-to-install, use 10%	R = 0.08 mm [0.00315 in], or a R/T = 0.45
Dynamic flex use 0.3%	R = 5.74 mm [0.226 in], or a R/T = 31

IPC-2223D
Sectional Design Standard for Flexible/Rigid-Flexible Printed Boards

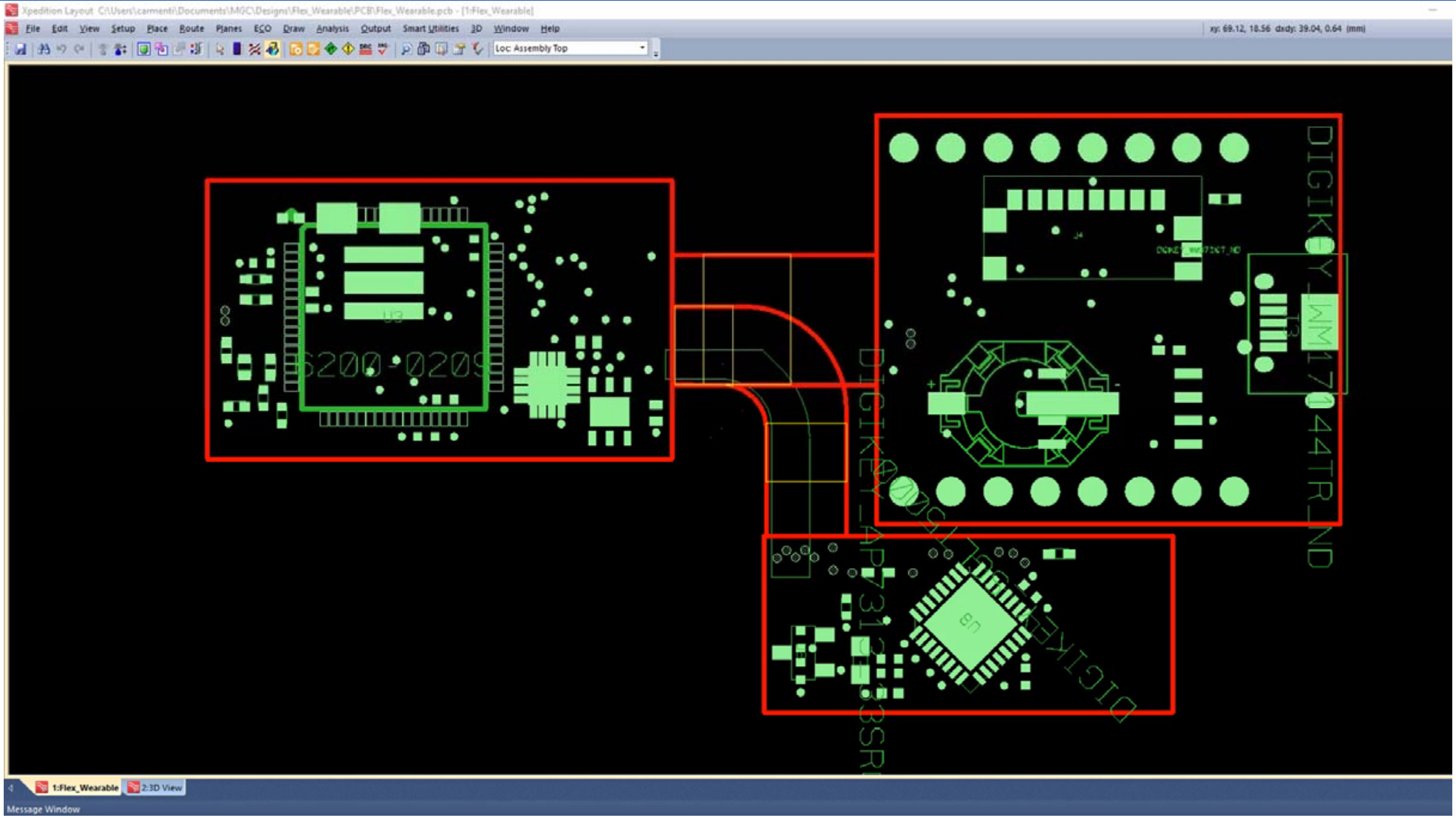
Fabricator - Best Practices

Fabricator interaction

- Stackup, keepout regions, bend requirements, stiffeners, etc., all need to be reviewed and agreed upon
- Other items to review:
  - Laminates and bonding materials
  - Surface finish
  - Cover layer design
  - Impedance control
  - Hole to interface distance (where the flex interfaces with the rigid)



Demonstration – Key Best Practices



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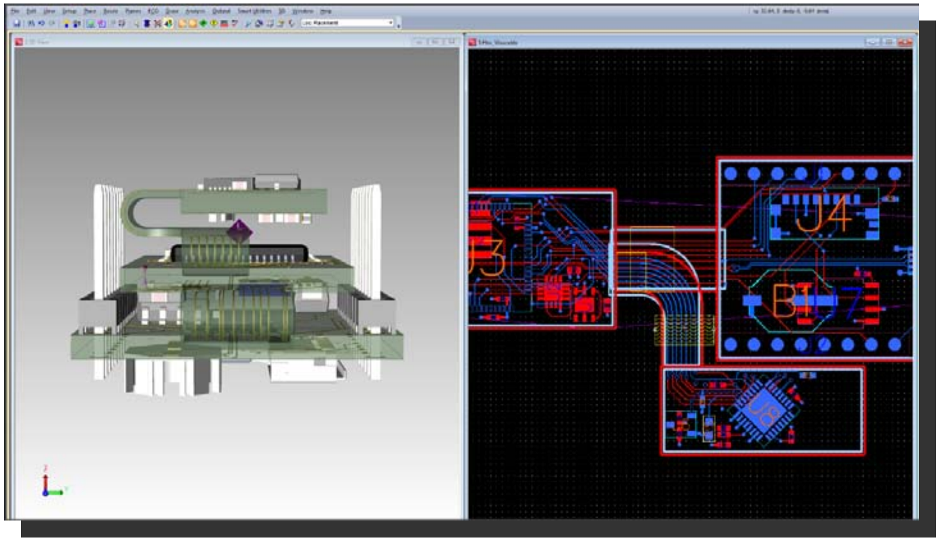
SUMMARY

Summary

- Design of a rigid-flex product is significantly different from the design of a rigid-only or flex-only product
- These tips and best practices are introductory in nature
- Invest in education on terminology, requirements, processes and best practices
- ECAD tools should facilitate process compliance and ensure correct-by-construction designs



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