Why Rigid-Flex?
Why Rigid-Flex?

**SIGNAL INTEGRITY**
- Elimination of parasitic inductance and capacitance
- Preservation of signal speed, power, and clarity

**WEIGHT/SPACE REDUCTION**
- Contiguous flex material is lighter than connectors and cables
- Same number of connections made in less space

**COST REDUCTION**
- Flex cost is less than rigid and connectors combined
- Illustrates the importance of a “Big Picture” approach

**ASSEMBLY**
- BOM simplification
- Reduction in number of required assembly steps
- Reduction in number of opportunities for error
- Reduction in number of required solder joints
Unique Shapes & Sizes

Space Shuttle
In-Flight Data Collection

Military Aircraft
Cockpit Control Panel Sensor

Aerospace - Fuel sensor

NASA

Rigid-Flex – Type 4

Flex – Type 3
IPC “Types” Defined (Types 1 & 2) – Single Core Flex

**Single-layer**
- Mil-P-50884 – Type 1
- One conductive layer, either bonded between two insulating layers or uncovered on one side.
- Access holes to conductors may be on either one or both sides. Access holes on both sides of a single-layer are more expensive since the substrate must be drilled or punched separately.
- Stiffeners, pins, connectors, components are optional.

**Double-layer**
- Mil-P-50884 – Type 2
- Two conductive layers with an insulating layer between, plus cover layers on outer layers.
- Plated through-holes provide connection.
- Access holes or exposed pads without covers may be on either or both sides; vias can also be covered on both sides.
- Stiffeners, pins, connectors, components are optional.

Source: IPC-2223
IPC “Types” Defined (Type 3) – Multilayer Flex

Multilayer

- Mil-P-50884 – Type 3
- Three or more flexible conductive layers with flexible insulating layers between each one; outer layers may have covers or exposed pads.
- Plated through-holes for connection.
- Access holes or exposed pads without covers may be on either or both sides.
- Blind or buried vias are possible.
- Stiffeners, pins, connectors, components are optional.
IPC “Types” Defined (Type 4) – True Rigid-Flex

Rigid-Flex
- Mil-P-50884 – Type 4
- Two or more conductive layers with either flexible or rigid insulating material as insulators between each one; outer layers may have covers or exposed pads.
- Rigid-flex is differentiated from multilayer circuits with stiffeners by having conductors on the rigid layers. Plated through-holes extend through both rigid and flexible layers (with the exception of blind and buried vias). Rigid-flex also costs more.
- Access holes or exposed pads without covers may be on either or both sides; vias or interconnects can be fully covered for maximum insulation.
- Stiffeners, pins, connectors, components, heat sinks, and mounting brackets are optional.

Source: IPC-2223
IPC “Types” Defined (Type 5) – Uncommon

PCB TYPE 5:
Multilayer Rigid-Flex board with three or more layers without plated thru holes

TYPICAL APPLICATIONS:
Cell phones, automotive and other consumer products. Designs rarely seen

INSTALLATION USE:
Use A and D

MARKET APPEAL:
Low

Source: IPC-2223 "Sectional Design Standard for Flexible Printed Boards"
IPC “Uses” Defined

**Use A:** Capable of withstanding “Flex to Install”
- *Typically installed once and re-installed for servicing or replacement only*

**Use B:** Capable of withstanding continuous flex (“Dynamic Flex”)
- *May have hundreds of thousands of flex cycles (flip phones, laptops, printers, etc.)*

**Use C:** High Temperature Operating Environment
- *Defined as 105°C or greater*

**Use D:** UL Recognition
- *Common in automotive applications*

*Source: IPC-2223*
Industry Specs Applicable to Rigid-Flex

- **IPC-4101** *Rigid Base Materials*
- **IPC-4202** *Flexible Base Dielectrics*
- **IPC-4203** *Adhesive Coated Coverlays & Bondplies*
- **IPC-4204** *Flexible Metal-Clad Dielectrics*
- **IPC-4562** *Metal Foil*
- **IPC-6013** *Acceptability Standard*
- **IPC-2223** *Design Standard*

Source: IPC-2223
Specifying Rigid-Flex Materials

Common Fab Drawing Notes:

Flexible metal clad base laminate shall be per IPC-4204/11 E1E2MX CU-W7-XS/XS

Rigid metal clad base laminate shall be per IPC-4101 L41XXXX CX/CX

Rigid base laminate prepreg shall be per IPC-4101 P41 XXXX

Coverlay material shall be adhesive coated film per IPC-4203/1 E1E1M2
**Rigid-Flex Stackup Basics**

**Coverlayer “Patches”**

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**“Low-Flow” or “No-Flow” Pre-Pregs**

Matching Copper Thicknesses within each Flex Core
Bonded vs. Unbonded Flex Cores

BONDED

Better EMI Shielding & Impedance Control

“LOOSE LEAF” (Unbonded)

Greater Flexibility

“Book Binder”

• No longer supported
• Shown as illustration only
Coverlayers

- Protect otherwise exposed copper on flex sections and are thus the equivalent of soldermask on rigid sections
- Selective to flex areas only
- Commonly called “Patches” or “Bikini Cuts”
“Closed Cavity” Method

- Protects inner flex surfaces from outer layer plasma, copper plating, etching processes
- “Caps” are routed away after outer layer processing
- Must have 0.010” min from bottom of cap to top of flex coverlay to have enough room for successful closed cavity cap removal

May Require Teflon Filler
Why the Long Lead Times?

Tooling/Processing Complexity

- CNC Programming/Routing
- No-Flow Prepregs
- Coverlayer Patches
- Rigid Cores
Why the Long Lead Times?

Typical 12 Layer Rigid BOM

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Total Process Steps: 50

Typical 12 Layer Rigid-Flex BOM

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Total Process Steps: 132

These individual items require 10 process steps or less before they are ready to be layed-up into the final panel.

Many of these individual items require 15 process steps or more before they are ready to be layed-up.

Rigid PCB = 50 Process Steps

Rigid-Flex PCB = 132 Process Steps!!!
Stiffeners (aka “Rigidizers”)

- Relatively inexpensive way to stabilize portions of Type 1, 2, and 3 flex pcbs
- Usually bare FR4 laminate, but can be other material
- Manually placed, bonded by adhesive or contact tape
- Can be labor-intensive, depending on the total number and size of stiffeners on each production panel
- More reliable than unsupported flex, but not as reliable as fully laminated Type 4 rigid-flex
Flex w/ Stiffeners vs. Rigid-Flex

Double-Sided Flex w/ Stiffeners

Potential Issues:
- Adhesive-Based Stiffeners Falling Off
- Through Hole Reliability Issues
- Traces Cracking at Stiffener Openings

4-Layer Rigid-Flex (Type 4)

Solution:
- Fully Laminated Rigid Sections
- Potential Issues Eliminated
Flex-Rigid Interface Reinforcement
(“Strain Relief”)
Minimum Bend Radius

Types 1 & 2 (single core): \( \text{Min } R = T \times 6 \)

Types 3 & 4 (bonded multilayer): \( \text{Min } R = T \times 12 \)

- No creasing allowed
- No plated holes in flexed areas

\( T \) (Thickness of Material)

\( R \) (Radius)

0.050” (1.27mm)

TENSION >

< COMPRESSION (potential delamination)
Panel Utilization (Affects Unit Price)

- No Nesting: Panel Yield 6 parts
- Circuits Nested: Panel Yield 8 parts
- Optimized Nesting: Panel Yield 10 parts

Part folded into shape after depanelization
Design Guidelines: Perpendicular Flex Trace Routing

Not Recommended

Preferred

Bending Zone

Bending Zone
Design Guidelines: Flex Trace Cornering
(Stress Point Concentration Avoidance)
Design Guidelines: Flex-Rigid Interface Keep-Out Zones

Copper Feature-to-Interface Min Spacing
0.100” [2.54 mm] Preferred
0.050” [1.27 mm] Minimum

PTH-to-Interface Min Spacing
0.110” [2.80 mm] Preferred
0.060” [1.52 mm] Minimum

Keep-Out Area

PTH & Via

Rigid

Rigid
Design Guidelines: Adjacent Flex Layer Trace Routing

STAGGERED CONDUCTORS
Preferred Construction

I BEAM CONSTRUCTION
Not Recommended
Design Guidelines: Flex Tear Prevention

1) Generous Corner Radius
2) Metal Reinforcement
3) Radii Separations
4) Drilled Relief (Zero Clearance)
5) Drilled Relief
6) Flex Material Patches
Guidelines: Fab Drawing Dimensioning

List Critical Dimensions Only
  - *Drawing-to-CAD Discrepancies are Common*

If Inclusive of Flex Section(s):
  - *Preferably State “Ref Only”*
  - *Otherwise +/- 0.5 mm (0.020”) Min Tolerance*
  - *Includes Overall Dimensions*
Design Guidelines: Flex Area Pad Anchoring (Tie-Downs)

*Less Reliable*

*Robust Design*
Design Guidelines: Flex Area Pad Anchoring (Coverlay)

**Pad Captured by Coverlay**

**Square Pads**

**Advantage:** Greatest Pad Hold-Down Capability

**Disadvantage:** Can Result in Excessive Adhesive Squeeze-Out
Design Guidelines: Flex Plane Patterns

**Solid Copper**
- *Least flexible, most effective shielding & impedance reference*

**Cross-Hatch**
- *More flexible than solid copper planes*
- *Potential EMI leakage (hatch pitch dependent)*

**Screened Silver Ink**
- *Most flexible (relatively thin vs. copper)*
- *Eliminates extra copper plane layers*
Combining High Density Technology w/ Rigid-Flex

Mechanical Vias, **Non-Conductive** Epoxy Filled & Cap Plated (Via-in-Pad)
Combining High Density Technology w/ Rigid-Flex

Laser surface microvias-in-pad (can be copper plated shut)
Combining High Density Technology w/ Rigid-Flex

Mechanical Buried vias w/ offset (unstacked) laser microvias
# Flex Design Guidelines

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Value-Added Services:
Field Applications Engineering (FAE)

- Early Design Support
- Rigid-Flex Concept Problem Solving
- Material Stackup/Impedance Modeling
- CAD Data DFM Review
- On-Site Technical Seminars
Thank you!

Todd Henninger  C.I.D.
Field Applications Engineer
North Central U.S. Region