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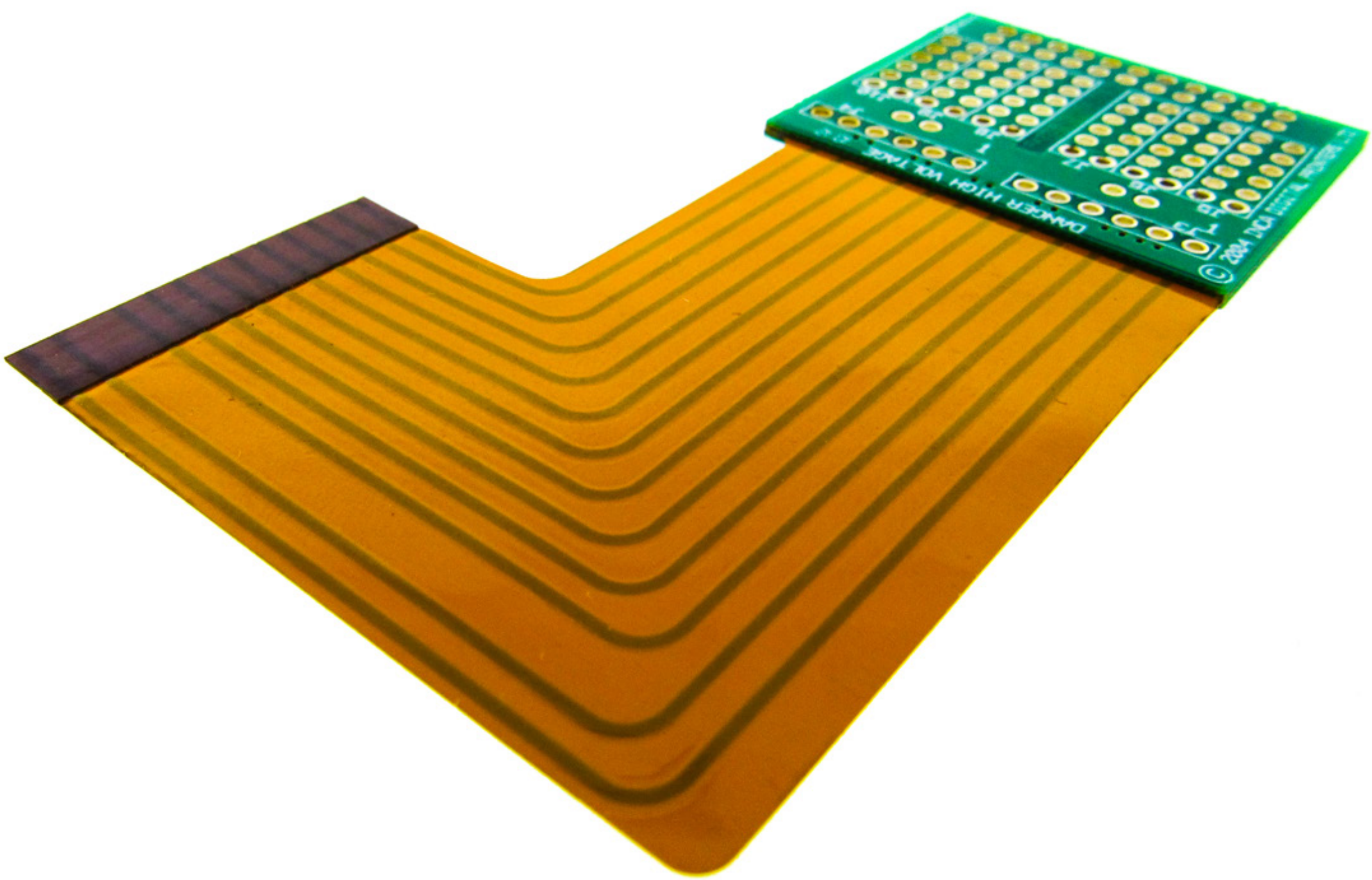
IPC 2223 Design Standard for Flex & Rigid-Flex Circuits

7 Important Elements of IPC 2223 and Their Impact on Performance and Reliability



Introduction

The IPC organization introduced the 2223 design standard in 1998 to address the need throughout the industry of how to both design and construct flexible and rigid-flex circuits in a manner that ensured a reliable finished part that met the design objectives. Since then, this design standard has been updated four times to reflect updated materials, design practices, manufacturing methods and, more importantly, address the needs of evolving technologies and increasingly sophisticated designs and applications. These in turn increased the demands placed on the finished circuits which prior methods where incapable of supporting.

IPC 2223 provides very wide and detailed information covering all elements that can be incorporated into either a flexible or rigid-flex design. As with any tool how effectively the requirements of this standard are applied is dependent upon identifying the elements that pertain to a specific design and applying those elements. Attempting to apply all of 2223 would be unnecessary as not all items apply to every design, would significantly complicate the design process and negatively impact the finished part cost.

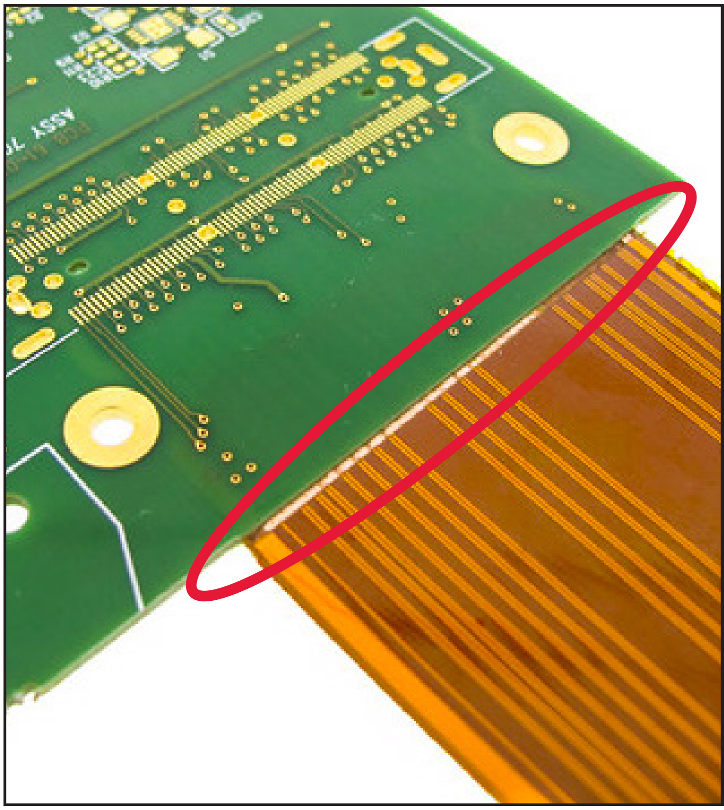
Within this Ebook we will review some of the more important elements of IPC 2223 and their impact on the performance and reliability of a finished rigid-flex circuit.

Important Element #1

Rigid-Flex Transition Via Keep Out Areas

A key element, impacting the reliability of rigid-flex circuits, is the location of any plated vias or holes in relation to the transition from a rigid section to a flexible section. This is covered in Sec. 5.2.2.3. This area of a design has the unique requirement that the polyimide coverlays, which encapsulate the flexible areas, must engage into the rigid areas by a small distance to ensure that they are captured by the rigid area lamination process. The coverlays are laminated to the flex surface with an adhesive, either acrylic or epoxy based. These adhesives have a very high coefficient of thermal expansion. If vias are drilled through the adhesive they are subjected to stresses caused by the thermal expansion and contraction of the adhesive. This creates a significant reliability concern as the plating within the via can crack when subjected to assembly reflow temperatures and in the field temperature fluctuations. IST, interconnect stress testing, has proven this can occur.

IPC 2223 specifies a minimum distance of 0.125” but this is considered generous. Most manufacturers can meet the intent of not allowing vias to be drilled through the coverlay adhesive with much smaller keep out distances. Such a larger distance as specified by IPC can also cause circuit layout challenges on high density designs. Epec’s standard minimum spacing requirement is 0.050” as measured from the edge of the hole and some designs may allow for 0.040”.



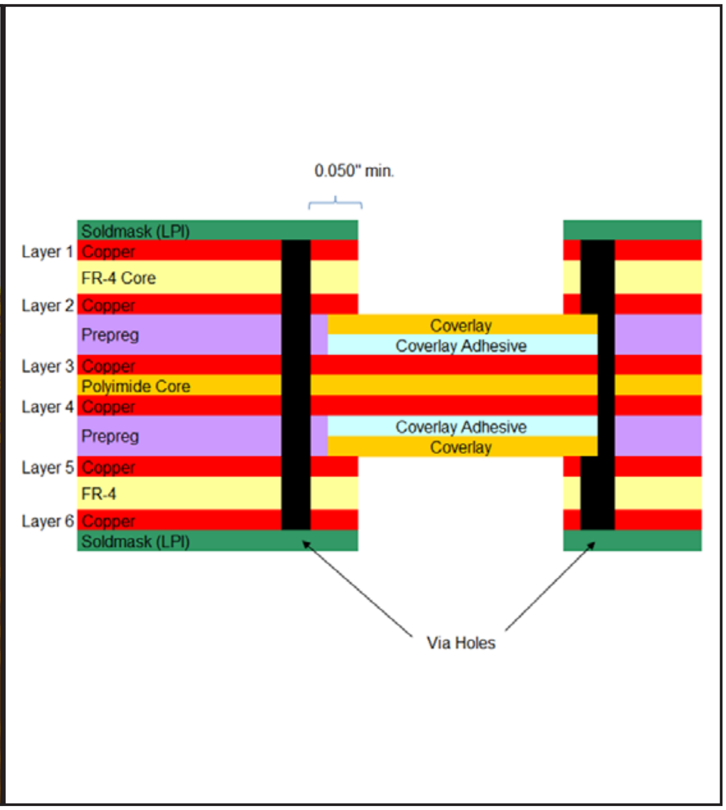


Image (left) via hole location meets IPC requirements. Image (right) is in violation.

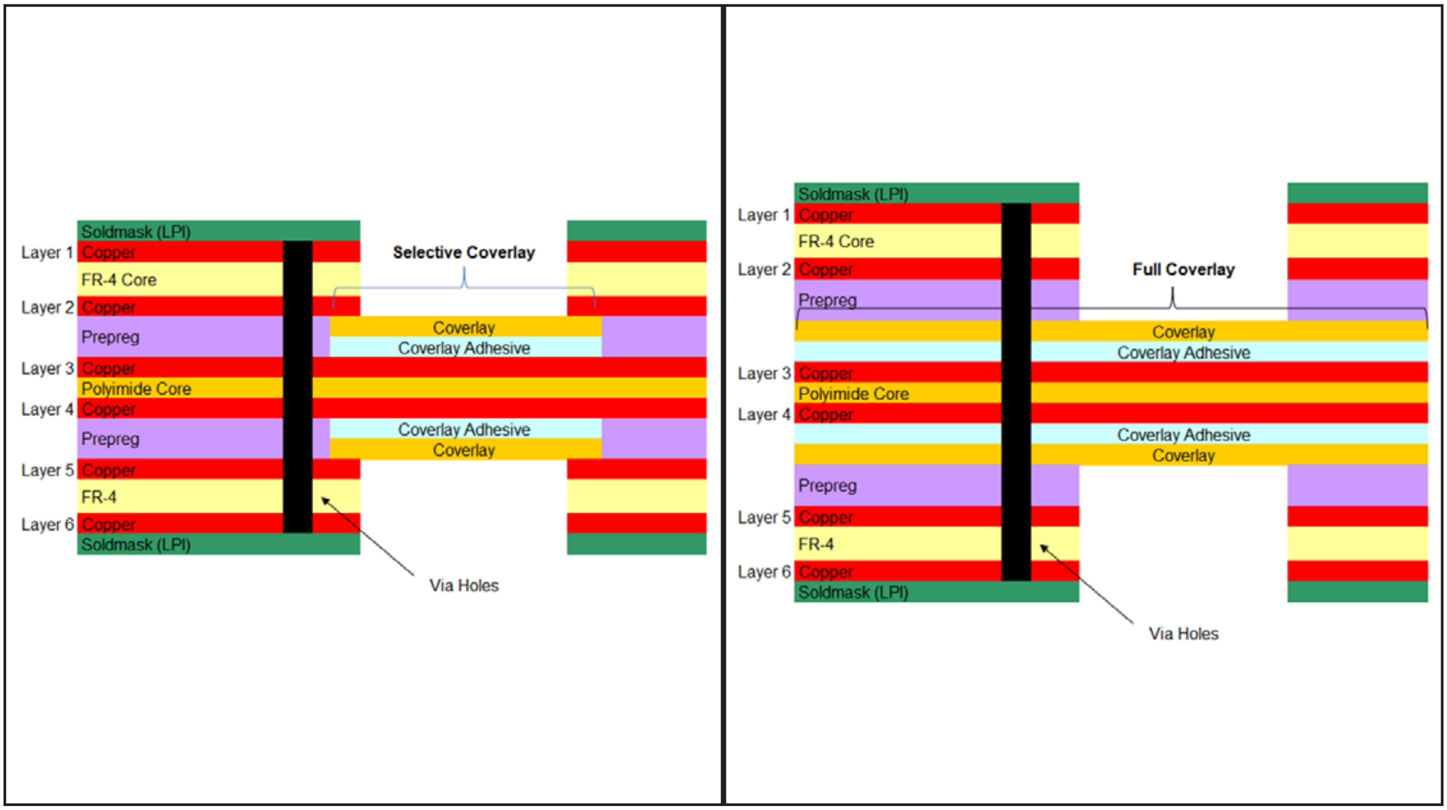
> VIA AND PTH SPACING TO THE RIGID/FLEX TRANSITION IS CRITICAL TO FINISHED PART RELIABILITY

Important Element #2

Rigid-Flex Selective Coverlay Construction

Evolving technology and design complexity, smaller VIA holes and RoHS assembly temperatures necessitated a change in the construction method of the flex area coverlays. Previous methods applied the coverlays throughout the entire design, including rigid areas. This old method resulted in all vias and PTH holes being drilled through the coverlay adhesives. As mentioned in the previous section, this exposes the vias to the thermal expansion issue of the adhesive and incurs the associated reliability issues.

IPC Section 5.2.2.2 defines that coverlays are to be applied “selectively” to the flex areas only with only a small distance of engagement into the rigid sections. This method has the added benefit that the coverlays and adhesives are not a component in the rigid area lamination which results in a stronger lamination. This method does have a slight cost impact as the coverlays require an additional machining process to remove the material from the rigid areas. It is important to define a selective coverlay construction in the data set to ensure the finished parts meet IPC 2223.



Correct selective coverlay (left). Coverlays engage rigid areas by approximately 0.025”.

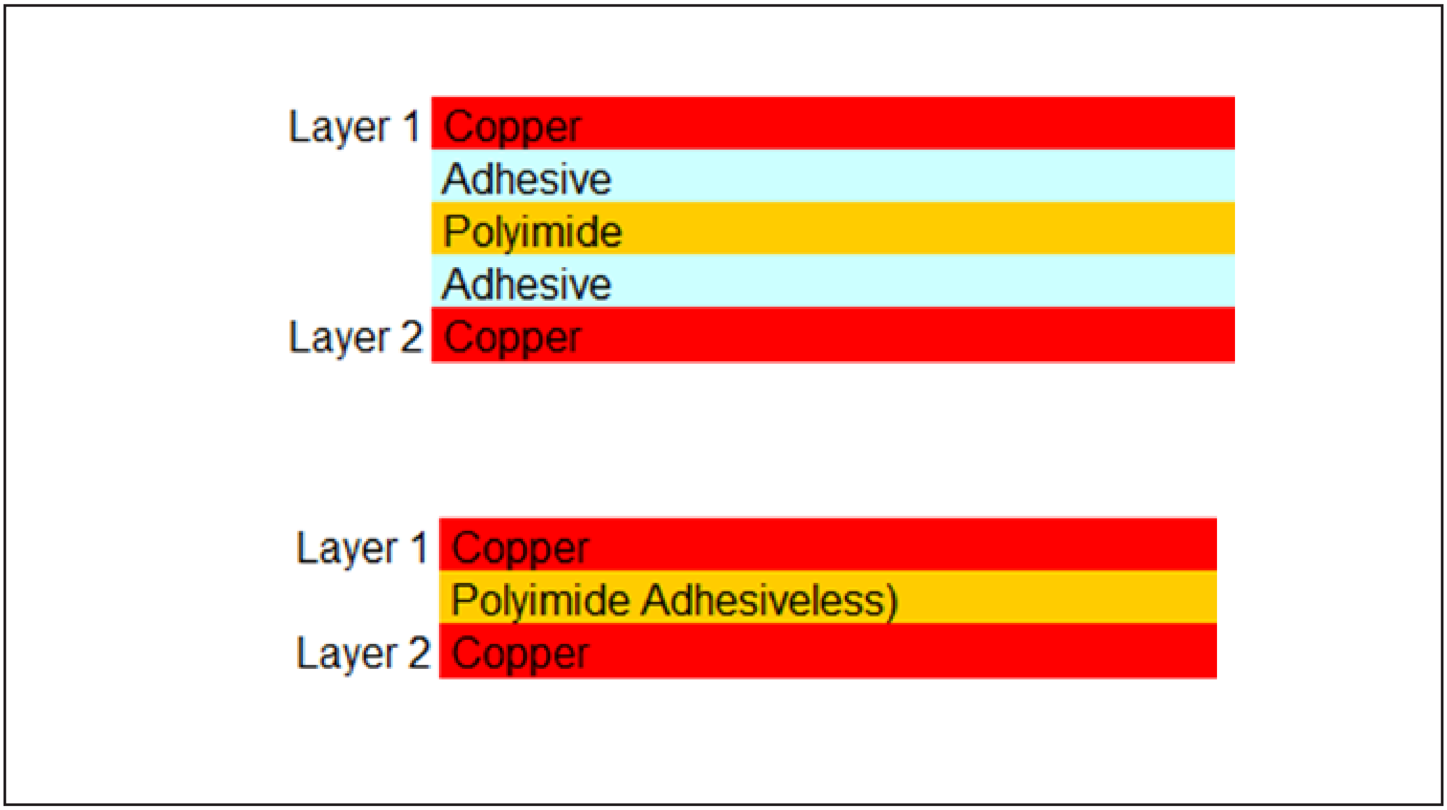
> A SELECTIVE COVERLAY CONSTRUCTION IS ALSO KNOWN AS A “BIKINI BUILD” SINCE THE COVERLAYS COVER ONLY WHAT NEEDS TO BE COVERED, THE FLEX SECTIONS.

Important Element #3

Adhesiveless Flex Cores

The flex core materials used play an important part in meet IPC 2223 requirements. Flex cores are available in two configurations that differ in how the copper is attached to the polyimide core. The original generation flex cores utilize a flexible adhesive to bond the copper layer to the polyimide. The latest generation has the copper directly attached to the polyimide without the use of an adhesive. This material is referred to as “adhesiveless” throughout the industry.

IPC 2223 specifically calls out the use of adhesiveless flex cores only. As the flex cores exist throughout the entire part using adhesiveless flex cores eliminates a source of adhesive from within the rigid areas and the associated via hole reliability concerns defined earlier in this Ebook. An added benefit is the reduced thickness, improved flexibility and improved bend reliability of thinner adhesiveless flex cores.



Adhesive flex core (top), adhesiveless flex core (bottom).

> SPECIFY ADHESIVELESS FLEX CORE BY THE IPC SPECIFICATION IN THE DRAWING NOTES AND GRAPHICALLY IN THE MATERIAL STACKUP IN THE FABRICATION DRAWING

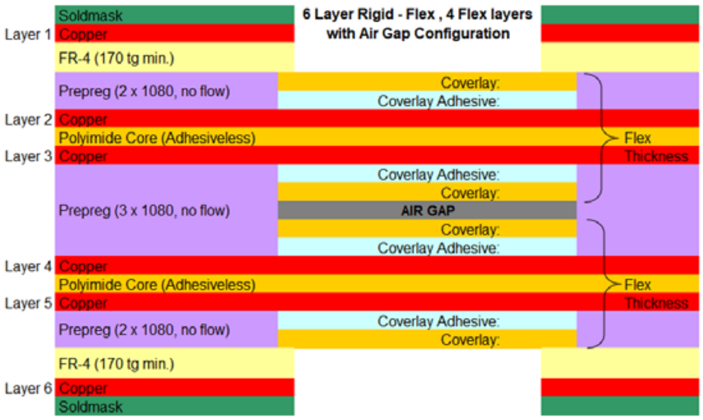
Important Element #4

Rigid-Flex Air Gap

Some designs require higher flex layer counts to meet the circuit routing requirements. Minimizing the flex layer count to 1 or 2 layers has the multiple advantages of improved flexibility, tighter bend capabilities, and reduced cost but is not always achievable in higher density designs. For 3 flex layers or more IPC recommends, whenever possible, configuring the flex layers as independent pairs rather than laminating all the flex layers together into one stack. This configuration is referred to as an “air gap” construction due to the open space between flex layers. The recommended air gap construction eliminates the all flex adhesives within the rigid sections and the associated via hole reliability concerns.

IPC 2223 does allow laminating all flex layers together for designs with two sided shielding or stripline impedance control requirements. This is with the recommendation that the use of adhesive layers be minimized and is not to exceed 10% of the total flex thickness.

An added benefit of the air gap construction is significantly improved flexibility. The flex pairs act individually when bent and provide almost as much flexibility as a two layer only configuration



Examples of both air gap and non-air gap constructions.

> DEFINE AIR GAP CONSTRUCTION REQUIREMENTS IN THE FABRICATION DRAWING NOTES AND MATERIAL STACKUP

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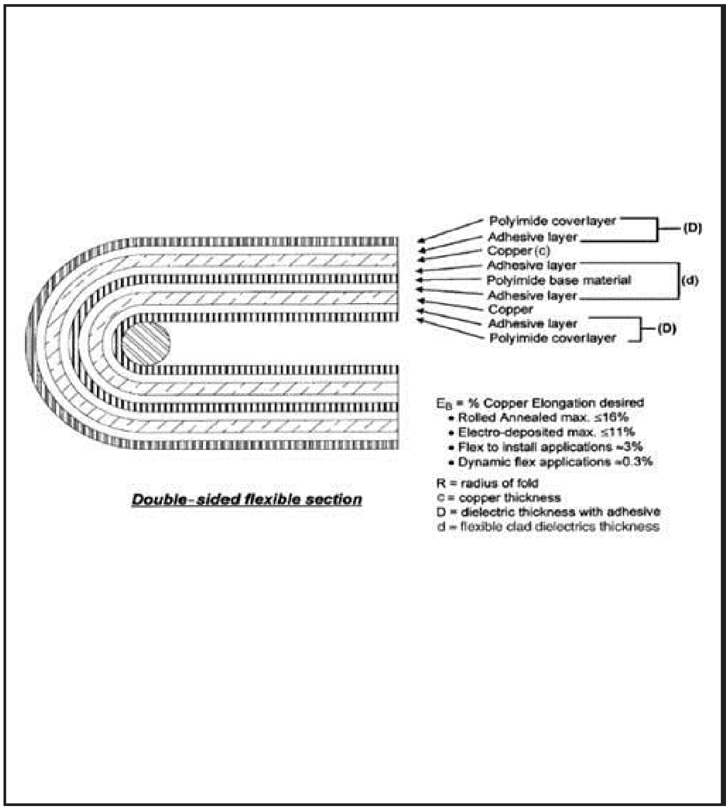
Important Element #5

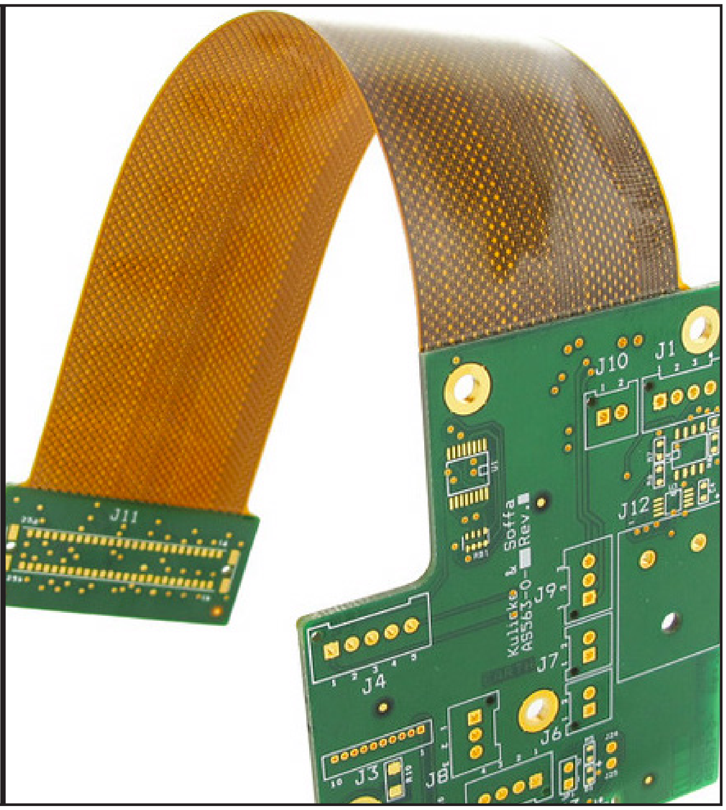
Minimum Bend Radius Capabilities

A key element to a successful design is ensuring the flex construction meets the bend requirements. The bend capability of a flex section is dependent upon the materials and material thicknesses used and cannot be impacted by the manufacturing process. IPC 2223 provides minimum bend recommendations for both static “one-time” or “bend to fit” as well as “dynamic” or “infinite bend” applications. These differ significantly in the allowable layer count, minimum bend capability, and the allowable copper type - either electrodeposited or rolled annealed. The minimum bend radius can be calculated or is commonly defined as a multiplier of the flex thickness. Bend to fit applications vary from 6x to 20x or greater depending upon layer count. Dynamic applications are typically 100x with a maximum of two layers.

IPC 2223 also allows, with specific guidelines, for a flex to be bent and creased with a zero bend radius. This is limited to very thin one and two layer constructions with the added stipulation that once the flex is creased it cannot be unfolded. A PSA, pressure sensitive adhesive/doubled sided tape, is often added in the fold area to permanently affix the flex and ensure that it is not inadvertently unfolded.

Many designs call out for a specific number of bend cycles. For these applications that fall between IPC’s guidelines, we recommend getting material and construction input from the flex circuit supplier and cycle testing the flex circuits as part of the design approval process.





Side view cutaway of a bent flex circuit and the impact on specific layers.

> MEETING THE DESIGN BEND REQUIREMENTS RELIABLY IS A KEY ELEMENT TO A SUCCESSFUL DESIGN. EVEN IF THE PART IS BEING BENT ONE TIME ONLY.

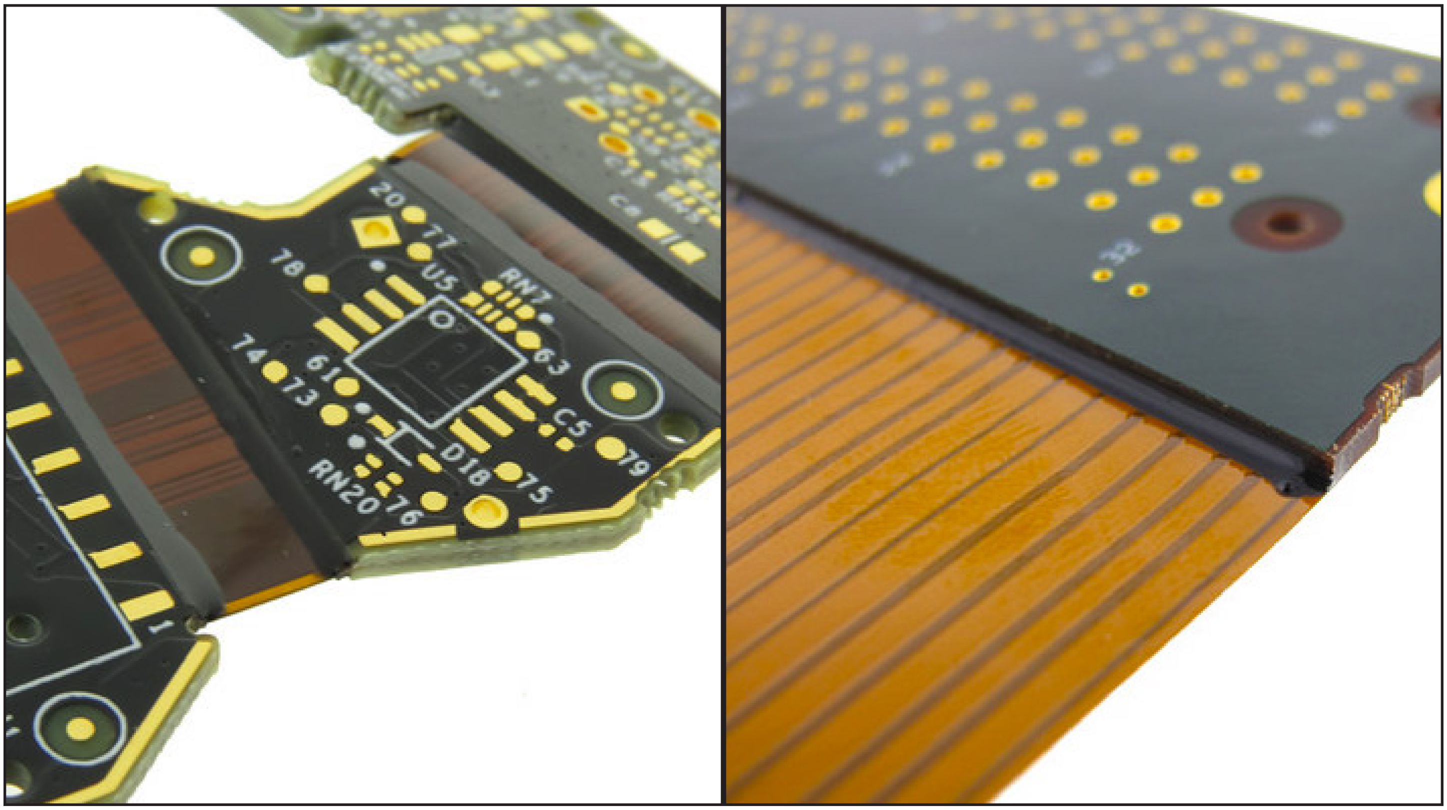
Important Element
#6

Strain Relief Fillets

A strain relief fillet is defined as a flexible bead, typically epoxy based, applied to the transition line from a rigid area to a flex area. This forces the flex to bend gradually and prevents it from being bent tightly against the rigid area which could damage the part.

IPC calls out for a minimum 0.010” height difference between the rigid area and the flex layers to allow enough space for the bead without it extending above the surface level of the rigid area. Strain reliefs requirements are defined in the fabrication drawing. A minimum and maximum horizontal dimension need to be defined as is commonly 0.040” to 0.100” to allow for manufacturing tolerances and the material flow properties. The most commonly used material is Eccobond 45/15 mixed in the flexible formula ratio. Others can be used but will need to be applied after assembly if they cannot withstand assembly reflow temperatures.

Many designs do not require or cannot utilize strain reliefs. Designs with very short flex lengths may result in the strain reliefs limiting the bend capabilities. The added cost may not be justified for relaxed bend applications. Reliefs should also be limited to the rigid to flex transitions that require it and not applied globally.



Epoxy strain relief examples. Black bead of Eccobond 45/15 applied at rigid to flex transitions.

> EPOXY STRAIN RELIEFS ARE AN OPTIONAL FEATURE THAT MAY BE REQUIRED TO ENSURE BEND RELIABILITY

Important Element #7

Pre-bake Requirements

The pre-baking of flex circuits, immediately prior to assembly, is an industry standard requirement that is called out in IPC 2223 section 5.3.5, IPC-FA-251 section 3.2.1.1.2 and by material suppliers (i.e. DuPont Pyralux Technical Manual section 5.23). This applies to all polyimide based flex and rigid-flex designs. Polyimide is hydroscopic and will adsorb approximately 2% by weight in moisture at 20°C and 50% relative humidity. The moisture must be removed otherwise it will lead to delamination of the flex area coverlays and/or rigid areas. If multiple assembly cycles are required, additional pre-bakes may be required depending upon time between cycles.

Pre-bake is performed at 120°C for 2-10 hours depending upon the specific design. Parts need to be configured in the pre-bake oven to allow air flow around all sides.

Pre-baking parts at the manufacturing stage is not a viable or practical option. Parts that are shipped vacuum packed with a desiccant will still contain moisture and require a pre-bake. Pre-baking the parts in advance of assembly and then storing the parts in a “dry box” is not an IPC or material supplier recommended practice.

Image of stiffener delamination due to lack of pre-bake prior to assembly.

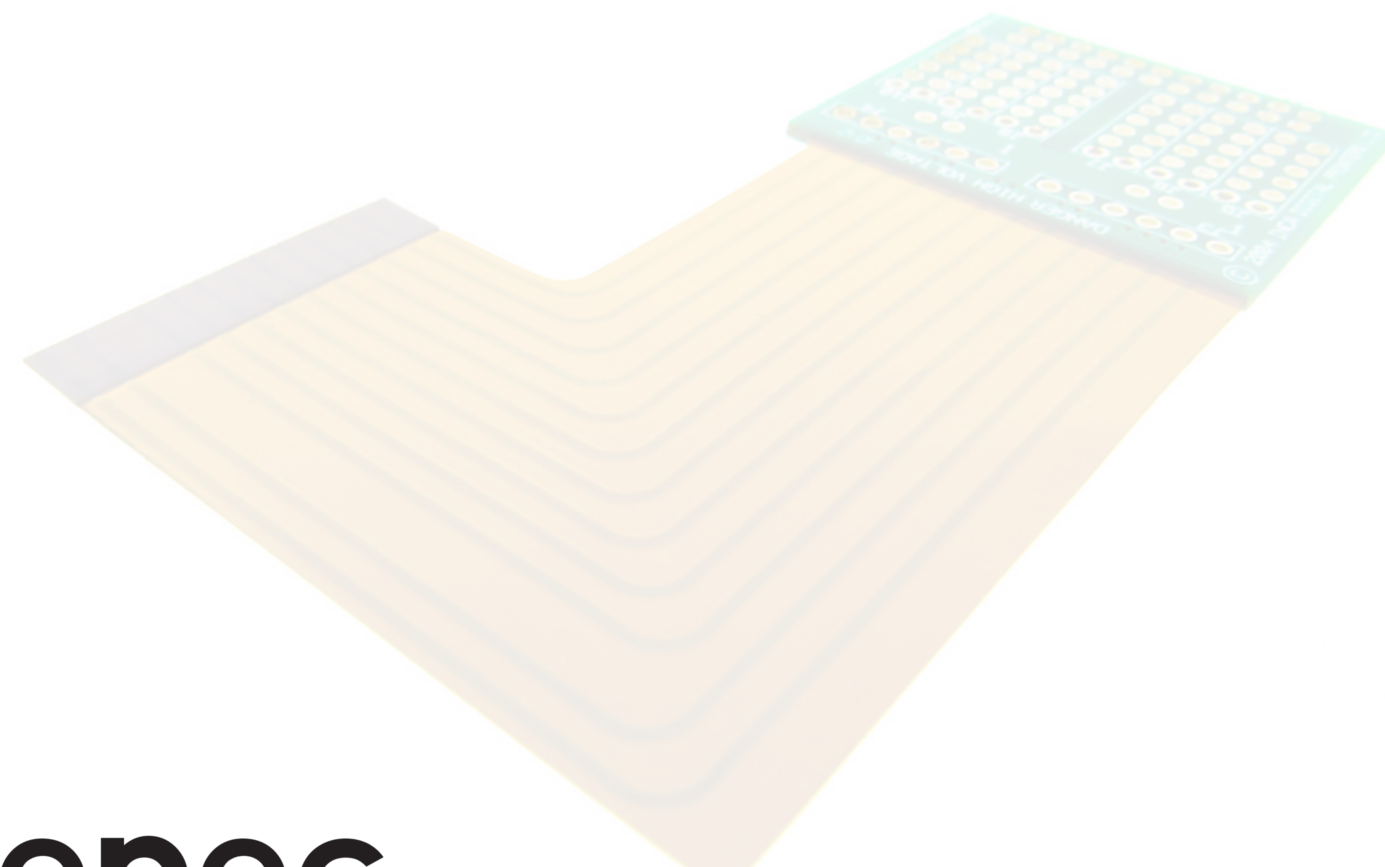
> PRE-BAKING OF FLEX AND RIGID-FLEX CIRCUITS PRIOR TO ASSEMBLY PREVENTS COVERLAY, SITFFENER, AND LAYER TO LAYER DELAMINATION

Final Thoughts

The collaborative effort between the IPC organization, material suppliers and manufacturers, that resulted in the creation of IPC 2223, has allowed flex and rigid-flex circuit designs to evolve dramatically.

The technology is now more than capable of meeting the ever-increasing demands required by today's and tomorrow's sophisticated electronic applications.

Applying IPC 2223 ensures reliability of the finished product.



About The Author

Paul Tome
Product Manager Flex & Rigid Flex

As Product Manager of Flex & Rigid-Flex Circuits, Paul oversees our entire flex & rigid-flex product line. Though Paul's main responsibility is customer technical support, he is involved in each project from the beginning conceptual stages to delivery. He works directly with customers on their specific design requirements and makes sure that each product is designed correctly, troubleshooting any issues that may arise in the process.

Paul came to Epec with 24 years of a great variety of experience in the electronics industry. He has been involved in all aspects of the industry including sales, engineering, and manufacturing. He has worked with PCBs and equipment manufacturing and has also been the owner of an engineering service and trust bureau.

Previously, he was president at Advanced Circuit Services. Paul's experience and expertise make him an indispensable part of Epec's team.

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Our knowledgeable staff has over 65 years of experience in the industry. We welcome the opportunity to put our skills to work for you! Please contact us with any questions or requests.

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