The following information about flex and rigid/flex should be included in order to complete manufacturing task:

1. class of product
2. materials to be used for construction
3. numbers of holes and hole size
4. number of layers
5. cross-sectional view of curcuit construction
6. coverlayer or covercoat opening locations
7. circuit outline with dimensions and datums
8. marking requirements, materials and locations
9. bend and flex locations and direction of bend
10. stiffener location and bonding requirements
11. tolerances for manufacturing
12. test points locations
13. special electrical testing requirements

The documentation sent to the vendor is the fundamental means of communication and, as such, must be as complete as possible to prevent potential confusion and loss of precious time.

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DEFINE CLASS OF PRODUCT
There are three generally-accepted classes of product as defined by IPC standards: Class 1, consumer products, Class 2, telecommunications,computers and general industrial, and Class 3, high-reliability. The definition of class will serve to provide guidelines as to how the product must be fabricated and inspected as well as provide performance requirements.

DEFINE MATERIALS TO BE USED FOR CONSTRUCTION
The materials to be used in construction of the circuit need to be defined to inform the manufacturer of which material the circuit should be made from. This includes issues of base polymer choice, adhesive type and copper foil type, along with the thickness of each of the above.

NUMBER OF HOLES AND HOLE SIZE
There is a need to define a hole count for each different hole size. This can usually be most easily accomplished by simply extracting data from digital files. The data are commonly used to help define the manufactured cost of the circuit.

NUMBER OF LAYERS
This information serves the needs of both manufacturing and sales. The layer count provides an indication of circuit complexity to sales and a key descriptor of the product to manufacturing.

PROVIDE CROSS-SECTIONAL VIEW OF CIRCUIT CONSTRUCTION
A cross-sectional view of the circuit is required to provide a visual cue as to what the designer expects his finished product to look like on edge. It is a helpful means of predicting overall thickness

PROVIDE COVERLAYER OR COVERCOAT OPENING LOCATIONS
The documentation package should also define the location of access points through the coverlayer or covercoat. In many cases, these will match the hole locations defined earlier; however, when surface mount devices are used, many other locations on the circuit will require access.

PROVIDE CIRCUIT OUTLINE WITH DIMENSIONS AND DATUMS
The final circuit outline is necessary to define the periphery of the circuit relative to the circuitry itself. These data are used to create the tooling required to remove the part from the panel, whether soft (such as a routing program), semi-hard (such as steel rule die technology), or hard (such as Class A die technology). The datums are important reference points to facilitate measurement. It is best if datums are called out based on features within the part rather than external to it. This allows the inspector to baseline his measurements on a real feature as opposed to an imaginary point outside the part. In addition,when features are distant from each other in a flex circuit, it is best to have a second or even third datum to facilitate measurement. This is because the length between features of a typical flex circuit may shrink or grow, making precise location of features difficult over long distances. Locally, however,the effects are not so great, and the part can more easily meet requirements.This scheme does not require the sacrifice of any tolerances but is merely a means of recognizing and accounting for the common realities of flex circuit manufacture. Figure 1 provides an example of such an approach.

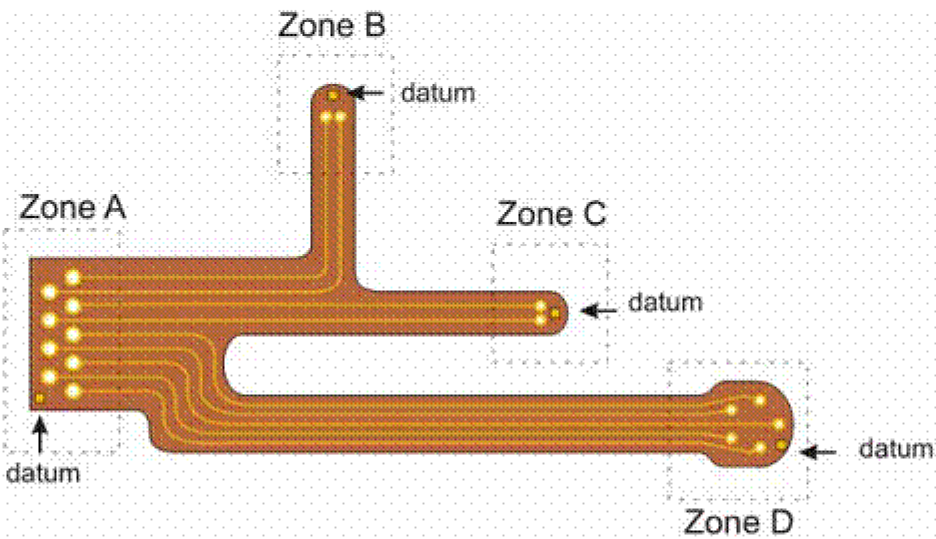


Figure 1 The use of multiple datums facilitates both accurate measurement and device placement.

MARKING REQUIREMENTS, MATERIALS AND LOCATIONS
Marking requirements must be defi ned to provide the circuit manufacturer the information needed to locate accurately and mark properly specific locations on the circuit. The choice of type and color of marking ink must also be defined at this time.

BEND, FLEX AND CREASE LOCATIONS
It is helpful to define the location of bend and flex areas as well as where crease lines may be required. This can be accomplished by placing special indicating features in the circuit artwork, or while marking is applied, and can also facilitate the assembly process by providing information as to which direction a bend must take. For example, dotted lines could be used to indicate bends in one direction, and solid lines could then indicate bends in the opposite direction. (See Figure 2.)

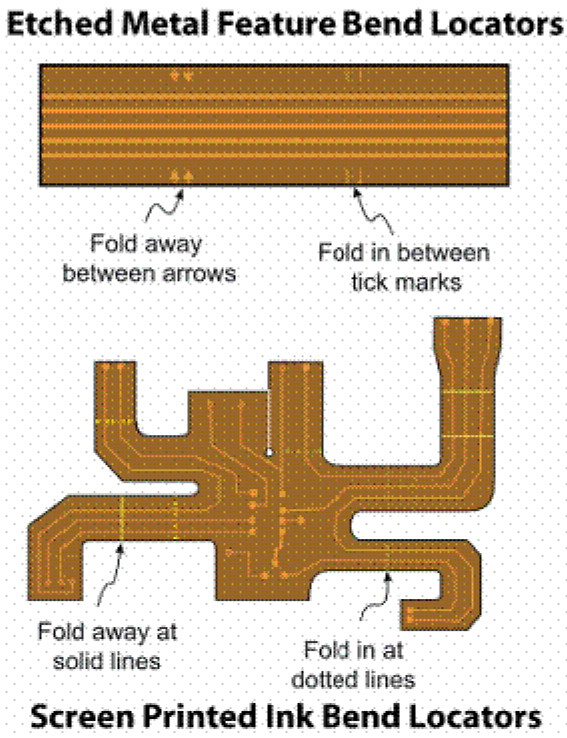


Figure 2 Indicators that provide information as to where and in which direction the flex circuit should be folded help to facilitate proper assembly.

STIFFENER LOCATION AND BONDING REQUIREMENTS
Location of flex circuit stiffeners and special bonding requirements or instructions should be provided in the documentation package. Requirements for special strain-relief techniques such as an epoxy bead along flex-to-rigid transformations should also be cited here.

SPECIAL PROCESSING AND/OR FINISH REQUIREMENTS
If special processes are required—such as the addition of special tear restraints or special finishes on the flex circuit—they should be specified. This includes calls for solder plating, nickel or gold plating.

TOLERANCES FOR MANUFACTURING
Manufacturing tolerances should be called out on the print. Most print formats provide a tolerance block near the title block for the drawing.Keep in mind that by nature of the product, flex circuit tolerances are or should be less stringent than those applied to rigid board constructions. As a result, the tolerance block should accurately reflect the capabilities of the finished flex product.

TEST POINT LOCATIONS
Test point locations should be defined in a digital data format. The use of test nodes in place of 100% testing of all points on a circuit can help reduce testing cost by limiting test points only to those required.It is important to remember that test probes will likely leave physical indentations on the metal surface due to the soft ness of the fl ex circuit base material. If this will be cause for concern by receiving inspection, it should be fully discussed with the manufacturer beforehand.

SPECIAL ELECTRICAL TESTING REQUIREMENTS
Should they be required, any special electrical tests should be defined in the documentation.

GENERAL GUIDELINES FOR DIMENSIONING AND TOLERANCING

Proper dimensioning and tolerancing of fl ex circuits is vital to achieving good manufacturing yield. While it is not possible to point out every possible situation where dimensions and tolerances can be used in such a way as to confuse the interpretation of a drawing, there are certain general guidelines that, if followed, can do much to minimize the potential for confusion. Following are a few such guidelines:

•Show sufficient dimensions so that the intended sizes and shapes can be determined without requiring the distances between features to be calculated (or assumed).
•Provide individual dimensions only once and check them.
•State all dimensions clearly so they can only have a single possible interpretation.
•Show the dimensions between points, lines or surfaces, which have a necessary and specific relation to each other or which control the location of other components or mating parts.
•Check dimensions to avoid accumulations of tolerances that may permit alternative interpretations.
•Provide dimensions to features, which are shown in profile making certain that the feature's dimensions are not ambiguous.
•Do not show dimensions to lines representing hidden surfaces.

SERVICE LOOPS

The addition of a small amount of length to the flex circuit beyond the design requirement is advisable for most flex circuit applications. This little extra length of material is commonly referred to as the service loop length

The purpose of the service loop is off er sufficient length to facilitate both assembly of the product and servicing of the product once in the field,if it should ever be required. The extra length also helps to compensate for small, unforeseen variations in both the package and the flex circuit.

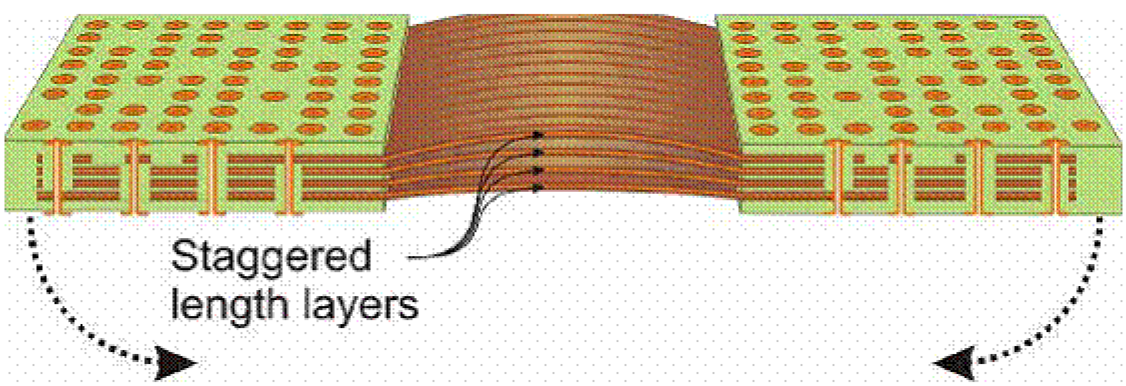


Figure 3 :Staggered length designs facilitate bending of the fl ex circuit; the circuit can only be bent in one direction by design

STAGGERED LENGTH CIRCUITS (BOOKBINDER CONSTRUCTION)

For ease of flexing multilayer and rigid fl ex designs, the use of staggered length design is commonly employed. The technique is accomplished by adding slightly to the length of each succeeding fl ex layer, moving away from the bend radius. (See Figure 3.)

A common rule of thumb is to add length equal to roughly1.5 times the individual layer thickness. This helps defeat whatever tensor strain might have otherwise been built up in the outer metal layers of the multilayer flex and prevents buckling of the center of bend layers (see Figure 4).

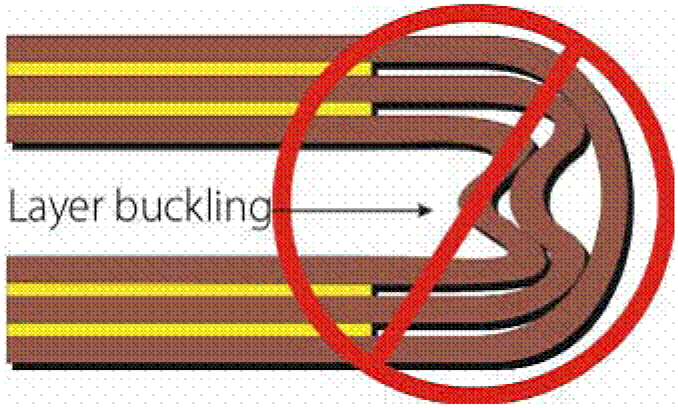


Figure 4 Without staggered lengths, layer buckling occurs.

CONDUCTOR SIZING AND ROUTING

In general, flex circuit conductor width and thickness are determined by a combination of current carrying requirements, the voltage drop allowance and/or characteristic impedance control needs. When designing flex circuits for dynamic applications, the use of the thinnest possible copper is recommended. Thus, it is important that the designer opt for wider rather than thicker traces to accommodate basic electrical needs or requirements. This practice assures maximum circuit flexibility.

ETCH FACTORS

An etch factor is a tool used by the manufacturer to compensate for isotropic etching process eff ects. It is recommended that the designer check with the vendor to determine if they want inclusion of an etch factor. Usually it is best if the manufacturer makes this adjustment, as they will be most familiar with their process and its capability.The typical line width loss (measured at the top of the trace) due to the etching process is approximately 2x copper foil thickness, although copper type, conductor pitch, etch mask, process chemistry and equipment can all influence the results.

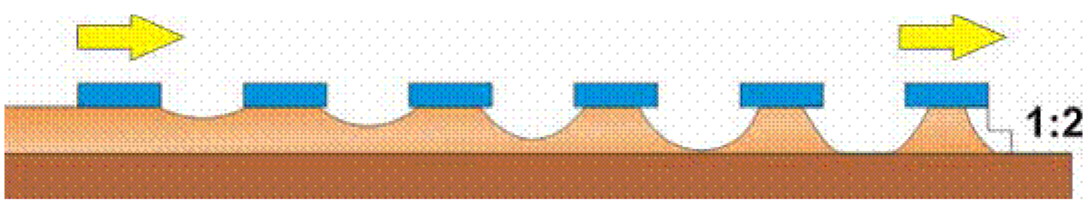


Figure 5 The etching process works laterally as well as down, at a ratio of roughly 1:2 laterally to down

The typical line width loss (measured at the top of the trace) due to the etching process is approximately 2x copper foil thickness, although copper type, conductor pitch, etch mask, process chemistry and equipment can all influence the results.

CONDUCTOR ROUTING CONCERNS

There are a few general issues related to conductor routing of a flex circuit. Th e fi rst item of concern is keeping to a minimum the number of crossovers in the layout. Th is will help to keep the layer count down and lower the cost. Newer CAD systems can respond to such a requirement, but the results may need to be massaged or optimized to make certain that the smallest possible area has been consumed in the process.

Routing of conductors on a fl exible circuit perpendicular to bend and fold is the recommended design practice. The purpose is to facilitate the bending or folding process and to minimize stress through the area. In addition, circuitry should be routed on a single copper layer through bend and fold areas whenever possible.

It is also recommended that designs avoid having right or acute angles (? 90°) in circuit routing. This is because they tend to trap solution and may over etch in process. They are also more diffi cult to clean aft er processing,so best practice dictates that corners should be provided with a radius if possible. Th e radius also improves signal propagation, as the refl ections at turns are reduced.With double-sided fl ex, when and where the conductors must be routed through bend and fold areas and when copper traces are on both sides, the circuit designer should design spaces to be approximately 2-2.5x the trace width. Preferably, the designer should also stagger traces from side to side.The purpose of this practice is to avoid the I-beam eff ect. This can be a critical concern in dynamic applications. (See Figure 6.)

Figure 6 Routing options for fl ex circuit trace corners. Avoid sharp corners if possible. A radius is best as it provides a smooth transition and mitigates potential issues related to stress risers.

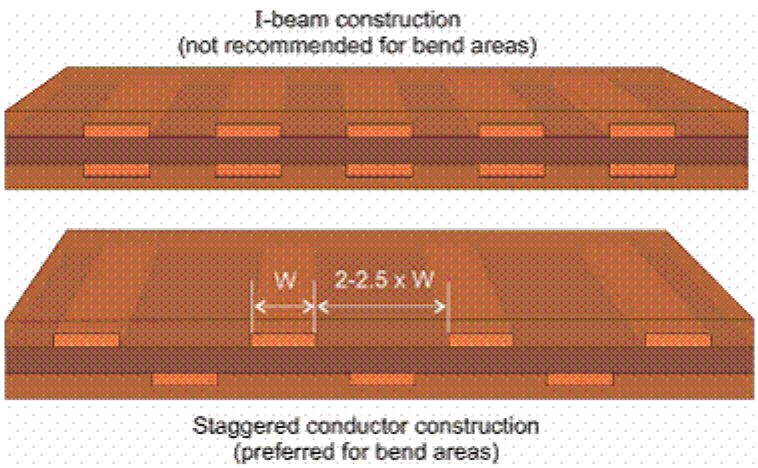
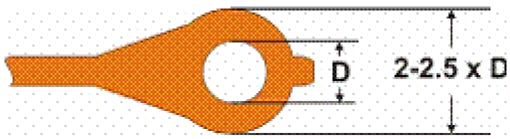


Figure 7 -Beamed vs. Staggered Conductors. I-beamed constructions increase the stiffness of the circuit through bend and fold areas. A better alternative, if space allows, is to stagger conductors for improved flexibility.

Finally, placement of vias within the bend area is highly discouraged as they will adversely affect bend formation and create unwanted points of stress and potential crack propagation.

HOLE SIZES FOR COMPONENT LEADS

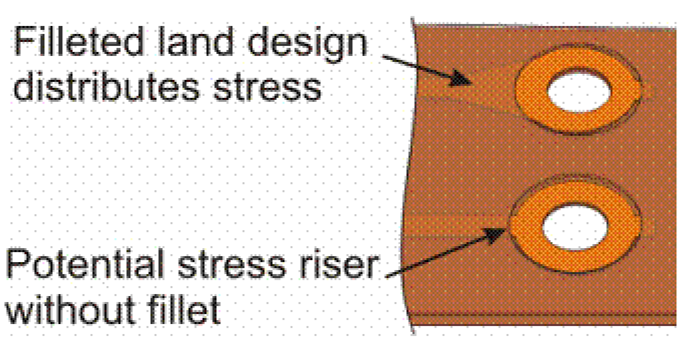
While surface mount technology has become the dominant interconnection technology for electronic component assembly, through hole components are still used in many applications. As a result, proper sizing of the hole remains an important design checkpoint. Finished hole diameter for through hole mounted components in flex circuits for most applications should be nominally 200-250µm (0.008-0.010") larger than component lead to meet best practice design requirements for automated component placement. However, this is not always possible or practical. One key advantage of fl ex circuits is that,because of the thinness of the circuit, smaller gaps between the component and the through hole can be reliably soldered—but the devices are more difficult to insert.
Best or preferred case fl ex design practice suggests that all lands or pads should be made 2-2.5x the hole diameter. Holding this value is primarily a concern with single-sided fl ex, where maximum solderable area is sought to ensure that a reliable connection can be made.
Again, as with drilled through holes, this ratio will not always be practical, as is the case with miniature connectors. In those cases where very small lands are mandated and pin in hole assembly is required, a plated through hole may be required to enhance solder joint reliability.



8: Through Hole Land or Pad Termination Sizing Maintaining a proper drilled hole to pad relationship is most important with single layer flex designs. Plated through holes can get by with smaller lands.

VIA HOLE SIZING

Vias can be designed as small as is practical for the manufacturer's yield.
Small vias off er great advantage for circuit layout, but circuit cost may be affected if they are designed too small, depending on what technologies are available for making holes in the base material. Current generation punching and laser techniques are capable of economically mass producing interconnection vias as small as 25-50µm (0.001-0.002"). In contrast,drilling, because of the higher cost of small drills, becomes more expensive as the holes get smaller. Because fl exible circuit base materials are thin, it is fairly easy to plate small through holes reliably. The small plated holes are also highly reliable in fl ex circuits. Th is is due in large part to the thinness of the base material, which results in a total material expansion that is low and less of a concern with respect to thermal cycling.



9: The practice of fi lleting pads helps to improve the reliability of the circuit by more evenly distributing stresses at the junction of the circuit land to the coverlayer opening.

FILLETING OF LANDS AND PADS

Termination lands and pads on flexible circuits should be filleted. This process increases pad area and helps to distribute stresses local to the coverlayer openings better, effectively relieving a stress riser condition that commonly causes failure if the fillet is not supplied or ignored. Earlier CAD systems had difficulty in producing these features, but today's more advanced systems can more reliably address the requirement for fillets without difficulty.

PAD OR LAND HOLD DOWNS FOR SINGLE-SIDED FLEX

Termination pads on single conductor layer circuits and surface mount lands on fl ex circuits of any layer count may require special land hold down techniques. With single-sided fl ex circuits, the use of special features variously referred to as tie down tabs, anchoring spurs, or rabbit ears may be employed to prevent the land from lift ing during soldering processes in cases where excessive heat is used. With new lead-free solders, this may become more important.

An important note on this subject is that features such as tie down tabs could well cause problems as the industry moves to higher data rate signaling, and they should be used with caution. Th e stubs associated with some tie down features are capable of acting like antenna and can broadcast noise within the package when higher frequencies are used.Thus, an evaluation of the approach may be warranted, depending on the nature of the design. Figure 9 shows typical hold down tab features and alternative designs.

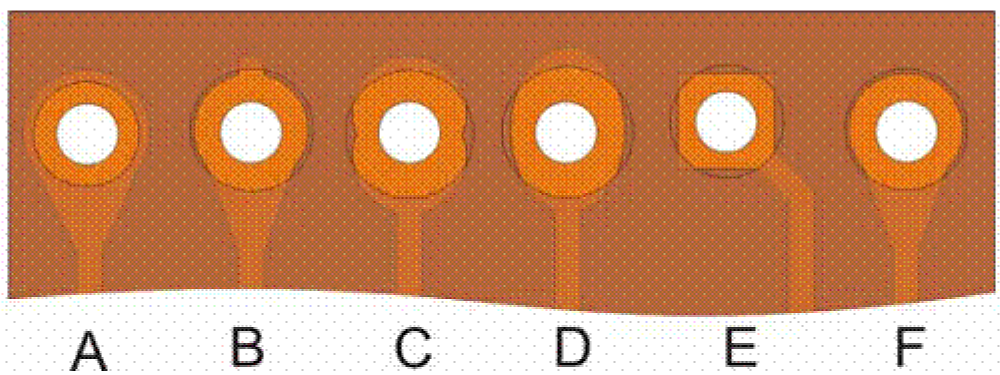


Figure 10: Various pad designs to help facilitate their capture by the coverlayer. (A) Standard filleted pad with full pad capture (B) Standard filleted pad with hold down tab (C) Overlapping pad design (D) Oval pad design (E) Corner entry to square pad (F) Plated through holes normally require only filleting.

SURFACE MOUNTING LANDS FOR FLEX

Surface mount in combination with flex circuit technology is now very popular as the world's flex circuit designers look to the success of Japanese products, which often employ flex circuits with surface mounted components. Surface mounting lands, however, oft en require a slight modifi cation of standard design rules when applied to fl ex circuit applications.

The use of holes or slots drilled or routed into the coverlayer before lamination is a common way for fl ex circuit manufacturers to access solder lands. However, if traces are routed straight into the land, misregistration of the coverlayer could result in the creation of a stress riser, as shown in Figure 9. The same concerns regarding through hole components hold true for surface mount land features. In Figure10(A), the potential stress riser condition is again shown. Side or corner entry to the land is more tolerant to misregistration (Fig 10 [B]). Laser-cut or mechanically punched or routed coverlayer openings can be made rectangular (Fig 10 [C]).

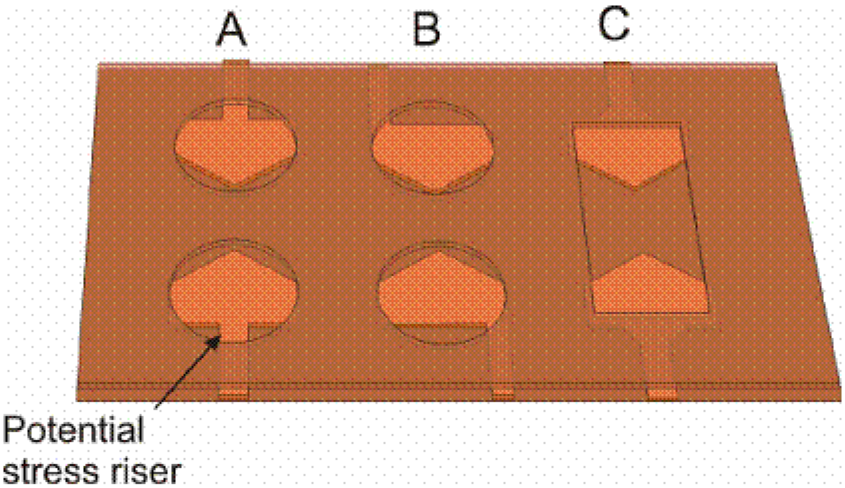
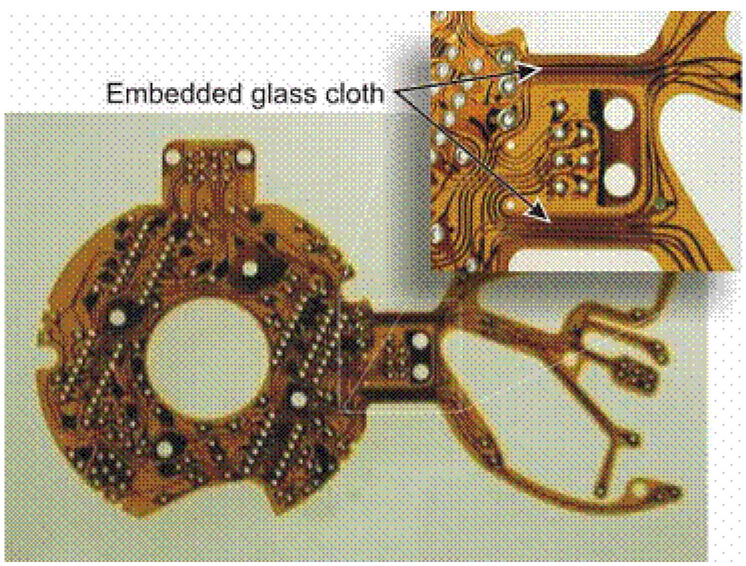


Figure 11 Coverlayer openings for discrete SMT components create special design concerns.

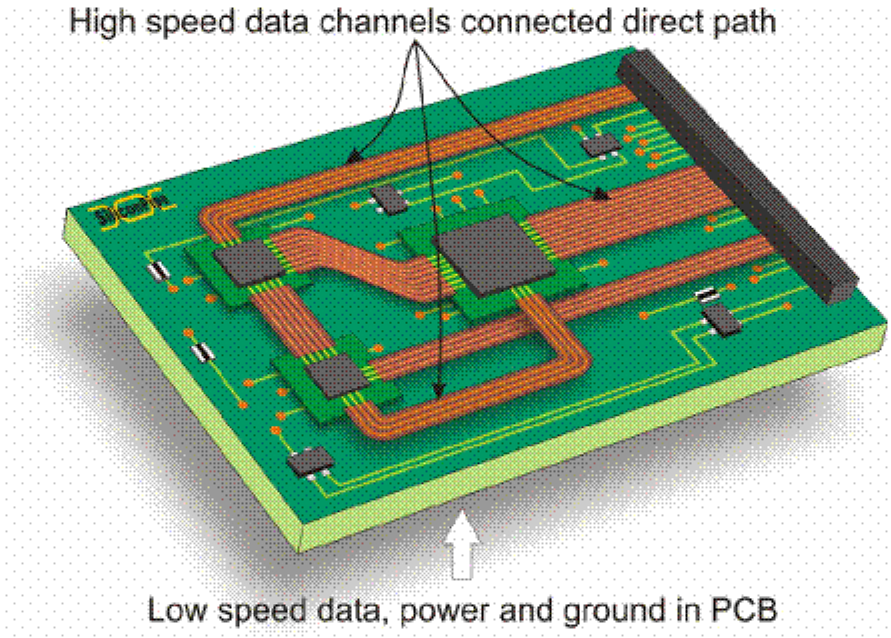
STIFFENERS AND REINFORCEMENTS FOR FLEX

Stiff eners or reinforcements are commonly used to support components on flex circuits. These important “add-ons” can be fabricated from a wide range of materials, depending on design need.



The choice of material is predicated on what objectives are sought (low weight, best heat sinking, lowest cost, best spring qualities, etc.)

BENDING AND FLEXING DESIGN CONCERNS
While fl ex circuits typically are employed simply to allow the user to form the circuit to fit the shape of the package (flex to install applications),there are still many applications that require some dynamic flexing. In fact, in most applications, the very act of placing the fl ex circuit into the assembly requires that the circuit be bent or folded. In some applicationsthis can occur several times. Flexible circuits are capable of enduring many millions or even billions of fl exural cycles, provided the design is properly matched to the task.



Those not involved in dynamic flex design should also take to heart the lessons of this process. For example, it is important to remember that even static flex circuits can be dynamically cycled by virtue of their application and design. Such events are common occurrences in circuits designed for any type of mobile equipment, such as automobiles and planes. For example, shock and vibration encountered by a vehicle can cause a flex circuit to endure millions of low amplitude, high frequency flex cycles. If dynamic fl ex design rules are not taken into account or are simply ignored, the potential for unexpected cyclic fatigue failure of an application subjected to shock and vibration exists. Attention to the few simple rules for dynamic flex provided here can benefit many flex circuit applications.They are, arguably, good practice for all flex circuit designs.

BENDING AND FLEXING TECHNIQUES
A number of clever approaches and techniques have been developed by engineers over the years to achieve the desired bending or flexing motion in a flexible circuit. The types of motions employed range from linear extension and contraction to rotational flexing through various small angles of 5° or 10° to more than 360°. Figure 12 provides conceptual examples.

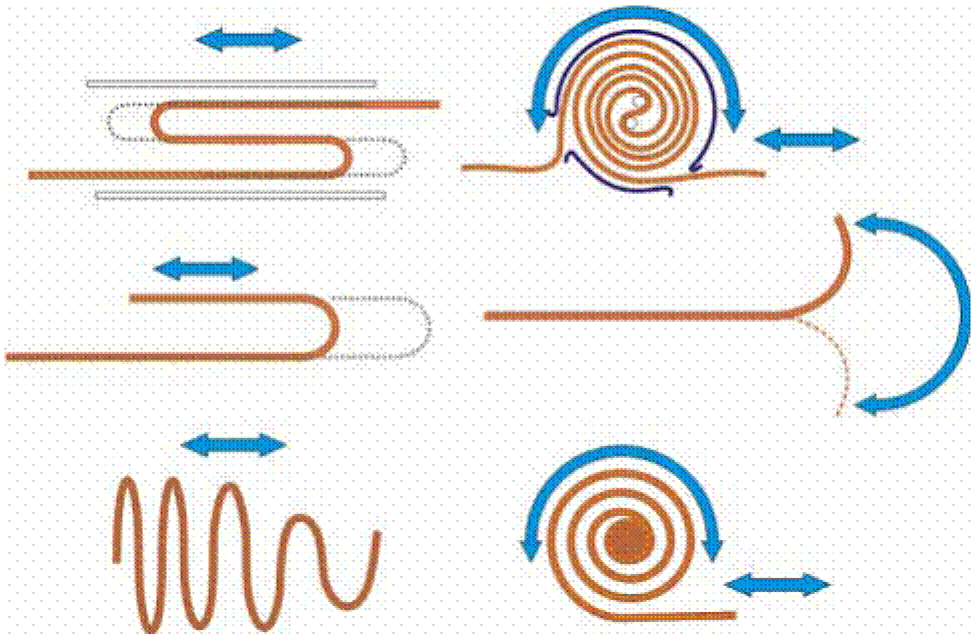


Figure 12 Various flexing and bending methods are illustrated. Clockwise from the bottom left: accordion flex, rolling flex, counter rolling flex (must be vertically space constrained), “window shade” flex, large radius or hinge type flex and coiled flex.