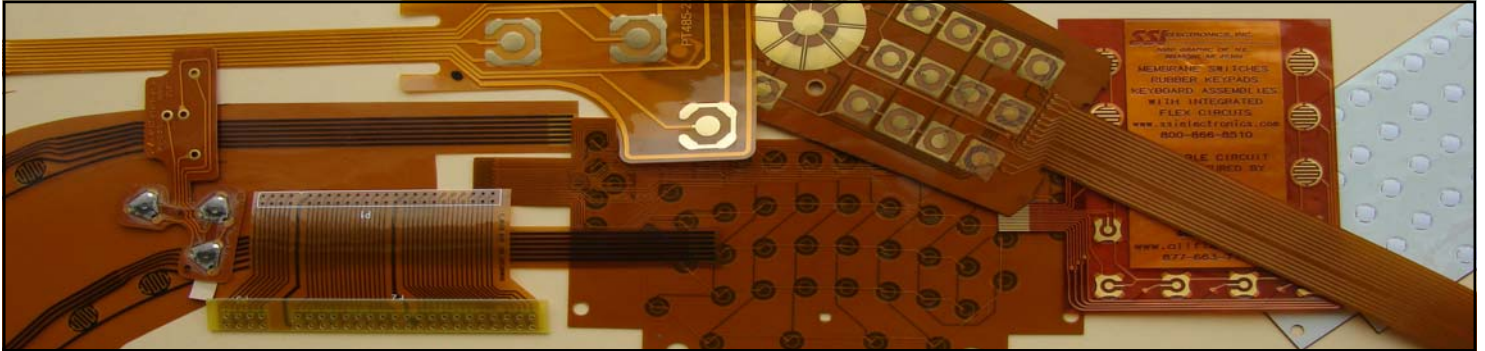


FLEXIBLE CIRCUITS: Design Guide



Flex Circuits vs. Other Types of Circuits

Flex Circuit or FPC: Copper-cladded film (usually polyimide) that is chemically etched to produce a specific circuit pattern.

Printed Circuit or Membrane Switch Circuit: Conductive Polymer Ink, usually silver, screen printed on thin film, typically polyester, to create a specific circuit pattern.

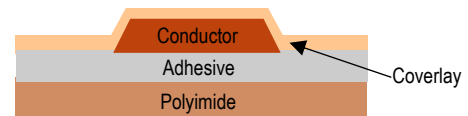
Flat Flexible Cable or FFC: Thin copper conductors that are laminated between two layers of polyester insulators to create a cable.

Printed Circuit Boards (PCB): Copper-cladded, fiberglass reinforced (rigid), laminate that is chemically etched to produce a specific circuit pattern.

Polyimide: Base Material for Flex Circuits

This amber colored material is the most common material used for flexible circuits. Polyimide is a synthetic polymeric resin that has been designed for high performance applications. It typically comes in thicknesses ranging from: .0005"-.005". Among the performance attributes of polyimide include: high temperature resistance, low out gassing, durability, solvent resistance and excellent dimensional stability.

Basic Flex Circuit Construction (Single-Sided)



Major Design Advantages of Flex Circuits

1 Reduced Space & Weight

Compared to standard Printed Circuit Boards (.063" thick), flex circuits provide a dramatic decrease in package size and weight. Flex circuits, which are typically .004"-.010" thick are even thinner and lighter than traditional cable options.

2 Solution to Interconnect Challenges

Interconnect problems can often be solved by flex circuits, which integrate the interconnects into the part. This eliminates the need for expensive cables and connectors.

3 Reduction in Assembly Costs

With the interconnections built into the flex circuit, there is often less connectors and thus soldering required. Additionally, the ability to pre-form the flex circuit assembly as well as its inherent flexibility, allows quicker installation, particularly in hard-to-reach areas.

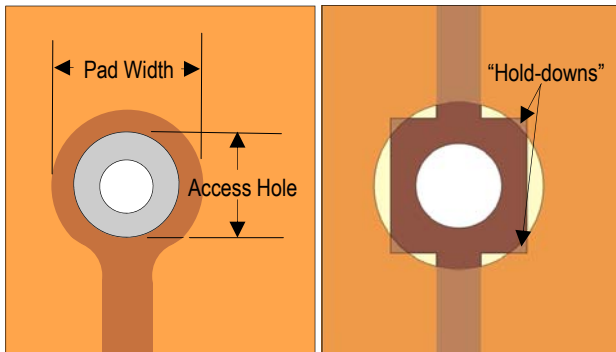
4 High Performance, Flexibility.

Certain applications simply require that the circuit and cable be flexible. Compared to other flexible options, flex circuits provide superior electrical and mechanical performance.

Design Features

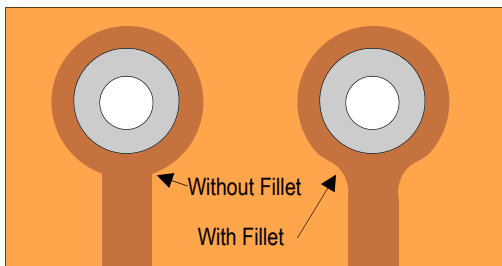
Pads

Pads should be designed so they are bigger than the access hole. If space is critical, "hold-downs" can be incorporated that extend outside the access hole.



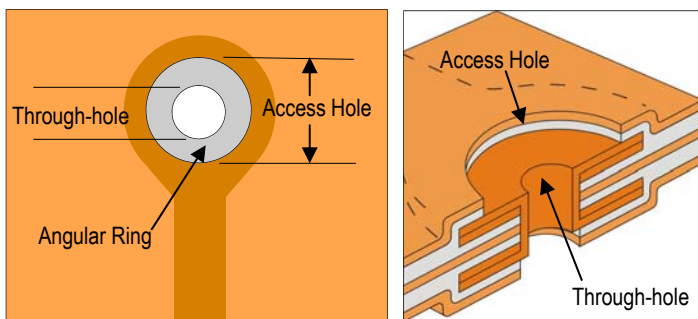
Fillets

When designing a pad, it is important to add fillets between the conductive trace and the pad. The fillet will help eliminate a stress point where these two entities meet.



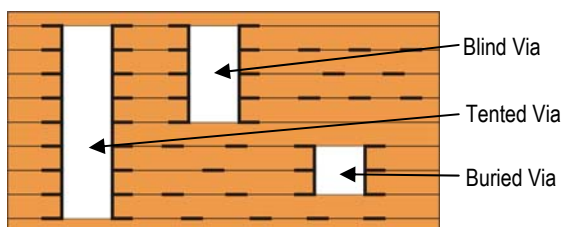
Through-holes

Through-holes provide a means to connect together the conductors that are on the top and bottom of multi-layered flex circuits. The plating process creates a conductive conduit between these two conductive planes.



Vias

The via is similar to a through-hole except it is covered on both sides with covers or other flex layers. Vias are helpful when space is a concern as they allow for conductors to be ran in areas that would have otherwise been drilled.



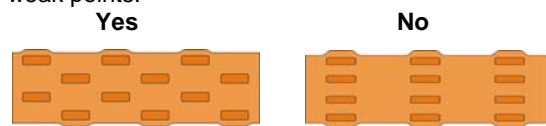
Designing for Reliability

When designing a flex circuit that will be regularly flexed in its assembled state, it is critical to consider several design factors that will impact the reliability of the flex circuit.

1. The thickness of the flex circuit has a direct impact on its flexibility. As a general rule, the following table should be used to determine the minimum radius of a given flex circuit.

Type	Min. Radius
Single Layer	6 times thickness
Double Layer	12 times thickness
Multi Layer	24 times thickness

2. Stagger the traces on multi-layer flex circuit to minimize weak points.



- Keep plated through holes and components away from flex areas.
- Conductor leads should be routed perpendicular to flex areas.
- Use fillets in all areas where conductors change width in order to make these transitions more robust against flexing.
- Incorporate strain reliefs in inside corners to prevent tearing.
- Bends can be formed in part by factory, which can increase repeatability of bend and eliminate hand assembly errors.
- Avoid having covers begin or end at bend areas in order to prevent delamination of cover from circuit.

Standard Material Selections

Common Base Materials

Polyimide	.0005"-.005"
"Adhesive-less" (Polyimide + Copper)	.002"-.005"
Polyester	.001"-.015"

Copper (weight & thicknesses)

.5 oz.	.0007" thick copper	4 oz.	.0056" thick copper
1 oz.	.0014" thick copper	5 oz.	.0070" thick copper
2 oz.	.0028" thick copper	6 oz.	.0084" thick copper
3 oz.	.0042" thick copper	7 oz.	.0098" thick copper

Solder Masks

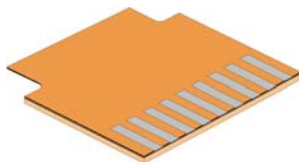
Polyimide Coverlay	.0005"-.005"
Polyester Coverlay	.0015"-.003"

Stiffeners

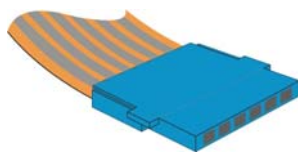
Polyimide	FR-4	Aluminum
Polyester	Ultem®	Steel

Interface Options

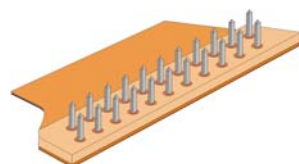
A wide range of interfaces can be used to connect a flex circuit to a PCB or other cable. Leads can be left bare so that they slide into board mounted connectors. Specialized connectors can be directly soldered to traces or standard connectors can be mechanically fixed to the tails of flex circuits. Below are illustrations of some of these interface options:



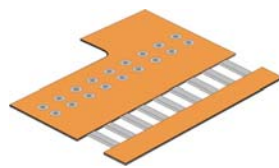
Bare traces (for ZIF/LIF connectors)



Female or male connectors

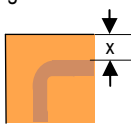
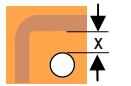



Posts with reinforcement



Solder tabs

Clearances/Specifications

Item	Standard	Minimum
Edge to Trace 	.020"	.008"
Trace to Cutout Clearance 	.024"	.012"
Radius of Trace 	na	.008"
Maximum Circuit Size	22" x 28"	na
Through-hole Size (dia.)	.010"	.006"
Trace Width	na	.0015"
Space Between Traces	na	.0015"
# of Layers	na	12

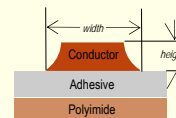
Tolerances:

Drill Hole Location Tolerance	+/- .003"
Through-hole Size	+/- .0015"
Operating Temperature	-85°F to 302°F

Traces/Leads

The traces on flex circuits are made out of copper. Various copper thicknesses (weights) are available depending on the current requirements of the applications. Additionally, plating options such as gold, nickel and tin are available which allow greater performance characteristics of the conductor to be achieved.

In order to maximize the ability of the trace to be consistently produced, the conductor widths need to be designed factoring the thickness of the conductor. Specifically, the conductor should be made at least five times wider than the thickness of the conductor.



Conductor width should be at least 5 times the conductor thickness.

Minimum Trace Width to Meet Electrical Current Requirement

	Copper Weight							
	1/2 oz.	1 oz.	2 oz.	3 oz.	4 oz.	5 oz.	6 oz.	8 oz.
.5 amps	.013"	.008"	.005"	.005"	.005"	.005"	.005"	.005"
1.0 amps	.028"	.017"	.013"	.005"	.005"	.005"	.005"	.005"
1.5 amps	.040"	.027"	.020"	.016"	.012"	.005"	.005"	.005"
2.0 amps	.053"	.040"	.030"	.0235"	.020"	.018"	.016"	.013"
2.5 amps	.080"	.060"	.042"	.0325"	.0285"	.024"	.023"	.018"
3.0 amps	.100"	.083"	.057"	.045"	.0387"	.035"	.030"	.024"
4.0 amps	.160"	.120"	.088"	.066"	.055"	.048"	.043"	.037"
5.0 amps	.225"	.158"	.118"	.09"	.074"	.065"	.059"	.048"
6.0 amps	.285"	.195"	.153"	.117"	.094"	.082"	.074"	.062"
7.0 amps	NA	.250"	.187"	.145"	.124"	.105"	.0905"	.075"
8.0 amps	NA	.307"	.232"	.180"	.1485"	.130"	.122"	.095"

Trimming & Cutting

The perimeter of a flex circuit as well as internal cut-aways can be cut using several different methods. For small volumes and/or very complex designs laser cutting can be used. For medium volumes, steel rule dies provide a modestly priced alternative. For higher volume and tighter tolerances male/female hard tooling is recommended. Below is a table with the approximate tolerances of these options:

Cutting Method	Approximate Tolerance	Up Front Cost
Laser Cutting	Within +/- .005"	None/Minimal
Steel Rule Dies	Within +/- .015"	Moderate
Hard Tooling	Within +/- .003"	High

The following information is critical in order to provide you with the most accurate quotation possible:

- ▶ overall size
- ▶ keypad centers
- ▶ diameter of corners
- ▶ size & location of cutouts
- ▶ testing requirements
- ▶ schematic: What side is pin 1 on?
- ▶ location of tail exit point
- ▶ tail length(s)
- ▶ number of layers
- ▶ plating requirements
- ▶ specifications
- ▶ features (stiffeners, connectors, etc.)

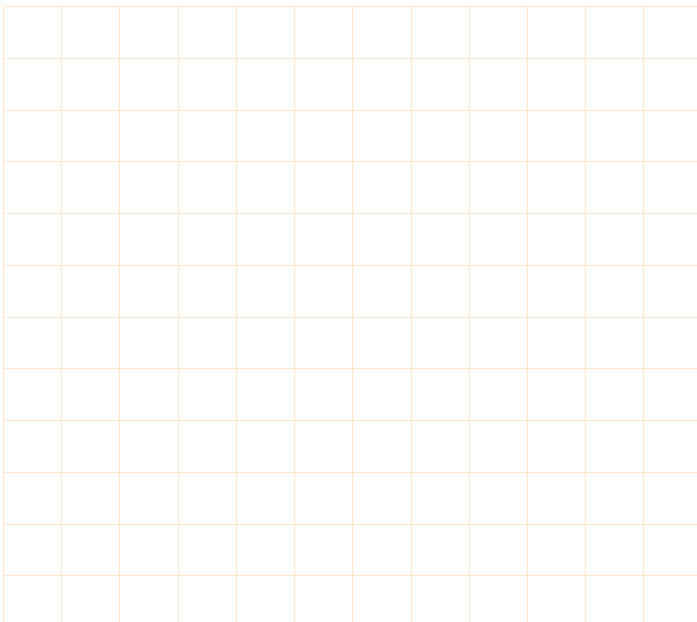
Are You Providing the Information in the Most Efficient Format?
(In order of preference)

1. GERBER FILE
2. AUTOCAD FILES (.DWG)
3. .DXF FILES
4. DETAILED BLUEPRINT (HARDCOPY)

AUTOCAD FILE INSTRUCTIONS:

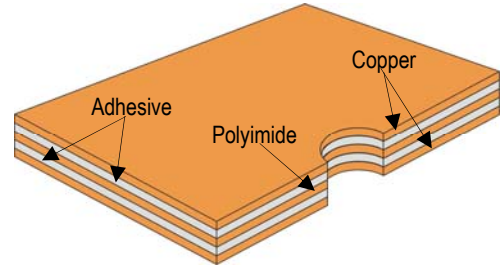
1. REDUCE FILES TO TWO LAYERS (DRAWING LAYER AND DIMENSION LAYER)
2. CREATE A DWG AND/OR DXF FILE (AUTOCAD VERSION 2000 OR OLDER)
3. PURGE ALL SYMBOLS, BLOCKS, AND XREFS

Sketch/Notes:

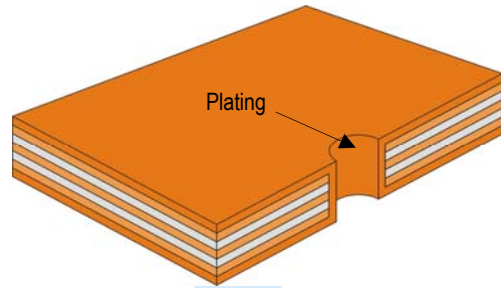


How is a Flex Circuit Manufactured? (Double-Sided)

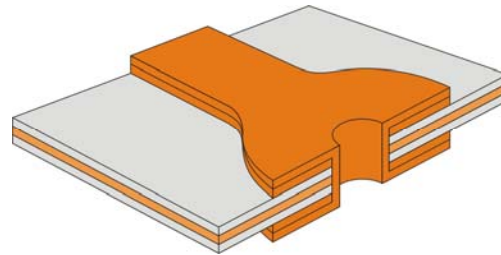
Double sided material is drilled:



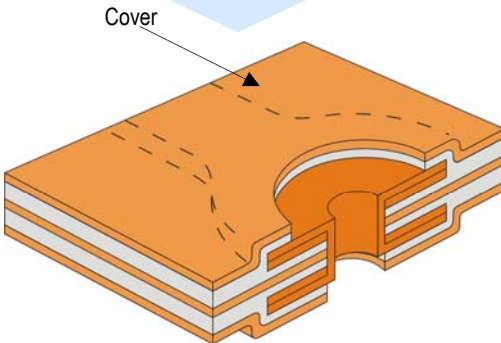
Through-holes are copper-plated:



Traces are etched in copper:



Polymide covers are drilled and laminated over copper:



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