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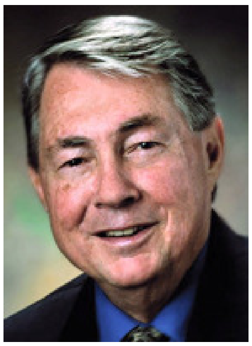
Designers Notebook: Flex and Rigid-Flex Circuit Design Principles, Part 1

Vern Solberg, Consultant | 01-27-2016



Flexible circuits represent an advanced approach to total electronics packaging, typically occupying a niche that replaces ordinary printed circuit board assemblies and the hard-wire interface needed to join assemblies. Flex circuits have an advantage over hard-wire interface because they fit only one way, eliminating wire routing errors as well as the time needed for testing and inspection.

Furthermore, flex circuit conductor patterns will maintain uniform electrical characteristics, controlling noise, crosstalk, and impedance. In addition to saving up to 75% on space and weight, flexible circuits improve overall product reliability. In essence, flex circuits furnish unlimited freedom of packaging geometry while retaining the precision, density, and repeatability of printed circuits.

Primary Flexible Circuit Structures

The four basic variations of flexible and rigid-flex circuits are defined as:

1. *Single-sided flex*: The most common type of flexible circuit *c*onsists of a conductive layer bonded between two insulating layer materials with SMT lands (when needed) accessible on only one side. The single Cu layer flex is the ideal circuit for dynamic flexing applications.
2. *Double-sided flex circuit*: Where copper foil is bonded on both sides of the base material. Vias connecting sides are punched, drilled or laser ablated and plated prior to chemically etching the circuit pattern. Finally, both sides of the circuit are covered with a dielectric cover-layer or cover-coat.
3. *Multilayer flex circuits*: This type of circuit consists of a number of conductive layers bonded together with dielectric between them. Plated through-holes are used to create the interconnection of the conductive layers. Although referred to as a flex circuit, pliability is considerably lessened with the addition of each layer.
4. *Rigid-flex circuits*: A rigid-flex structure consists of flexible circuit(s), which are then bonded onto or laminated within a rigid dielectric material. Flexible dielectrics provide unlimited conformability between rigid sections of the circuit commonly utilized for component mounting and system interface.

The design guidelines for flexible circuits, although similar to rigid circuits, have distinctive differences that are influenced by specific applications and the intended operating use environments.

Design for Operating Environment

Although the actual use environment may not subject the flex or rigid-flex circuits to excessive conditions, qualifying the end-product often requires thermal cycle testing (typically based on worst-case environments). Consumer and commercial products, for example, are not expected to be exposed to thermal conditions greater than 60°C; however, qualifying products for industrial, automotive and aeronautic applications will require reliable operation at both high and low temperature conditions (+95°C to -55°C).

Base Material Selection

Base material for flexible circuit applications includes both polyester and polyimide films. While polyester-based material may be considered for a number of cost-sensitive consumer applications, polyimide-based materials will continue to be specified for the more demanding environments noted above.

- *Polyester films* may not be the first choice for a number of applications but it does furnish excellent electrical properties, has relatively low moisture absorption potential and is thermally stable (capable of continuous operation at 105ºC). The material exhibits good to fair dimensional stability, is resistant to most chemicals and is the least expensive of the commonly used dielectric materials.
- *Polyimide films* have excellent electrical properties, the highest operating temperature capability (>200ºC) and good to excellent dimensional stability. Although the material furnishes excellent chemical resistance (acetone, methyl alcohol, toluene, and trichloroethylene) it has a relatively high moisture absorption rate and is significantly more expensive than polyester films.

Non-reinforced Dielectric

Polyimide remains the favorite alternative for flex and rigid-flex applications because the material is mechanically tough and easily withstands exposure to most harsh operating environments. The designer of the flexible circuit has a fairly wide range of material choices. The films, for example, are furnished in thicknesses that range between a very thin 12 microns (0.0005”) and 125 microns (.005”). For a majority of applications the 50-micron (0.002”) thick material will be specified; however, 25.0-micron (0.001”) thick films are often selected for complex forming conditions or, in dynamic applications, to maximize the circuits’ flexibility. Additionally, copper foil can be furnished on one side or both sides of the dielectric base. The copper foil is commonly laminated onto the surface of the polyimide film using a thin layer of modified acrylic, epoxy, epoxy prepreg, or phenolic butyral. Although copper foil can be furnished on both sides of the flexible base, furnishing copper on only one surface will be significantly less costly than the circuit requiring two-sided copper.

Copper foils are rolled and annealed and furnished in thicknesses of 17.0 microns (~0.0007") and 34.0 microns (~0.0014"). Foils as thin as 5.0 microns (~0.00018”) can also be furnished for semi-additive build-up plating when very high-density circuit routing is required. There are also polyimide films furnished with copper that is cast or deposited directly onto the films surface. These products are generally designated as adhesiveless. The adhesiveless circuits are more pliable and excellent for higher reliability applications, but the supply base is more limited and can be cost prohibitive for many consumer or commercial applications.

Reinforced Dielectric

Material selected for the rigid areas of the circuit is typically reinforced with a woven glass fiber. A key concern is how the material responds to multiple exposures to thermal extremes during the fabrication and assembly process. Material selected should exhibit minimal Z-axis expansion and furnish a higher thermal threshold before decomposition occurs. These factors will contribute to avoiding delamination during the product’s intended life cycle. All materials selected for the rigid-flex circuit will be certified to meet a flammability rating established by Underwriters Laboratory (UL).

Another factor that will influence material selection is the glass transition temperature (Tg), the temperature at which the material begins to relax. For example, the better grades of epoxy-glass laminates have a minimum Tg of 170ºC, while the polyimide-glass composites Tg minimum is extended to 200ºC. In regard to decomposition temperature (Td), epoxy-glass material specified in UL/ANSI FR4/126 and FR-4/129 specifies a minimum of 340ºC.

Note: Polyimide films and glass reinforced and non-reinforced organic base material specifications are detailed further in IPC-4101 and IPC-4102.

Before proceeding with the circuit layout, the designer must consider a number of requirements exclusive to the fabrication of flexible circuits. It’s important to discuss base material sets and alternative fabrication processes with your supplier prior to finalizing the design.

Vern Solberg is an independent technical consultant based in Saratoga, California specializing in SMT and microelectronics design and manufacturing technology. To reach Solberg, click here.