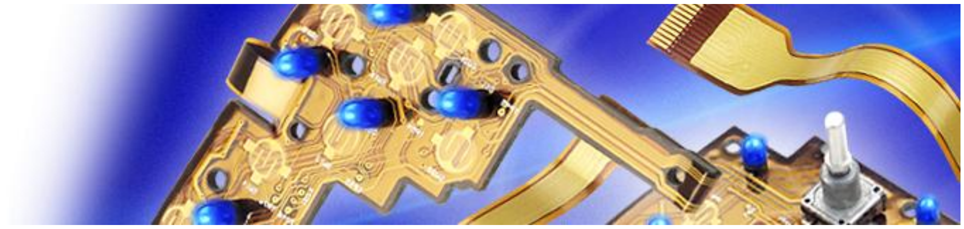

# Flexible Printed Circuit Manufacturability, Configurations, and Applications

In addition to widespread aerospace applications, flex circuits can now be found in under-the-hood automotive control modules, laptop computers with extremely tight packaging requirements, telecommunications equipment, and cameras. Flex circuits are increasingly supplanting rigid boards, especially in applications where thickness is a constraint. In order to take full advantage of the adaptability of flex circuitry, users and designers should be familiar with the versatile interconnect, from its simple and advanced forms to its assembly possibilities, and from passive components to chip-on-flex.

## Configurations and Applications

Single-sided flexible circuits, the simplest and easiest to manufacture, commonly consist of a layer of copper foil laminated to a layer of dielectric material. Another layer of insulating material may be laminated to the foil to encapsulate the conductors. For dynamic applications, single-sided circuits provide maximum flexibility; a properly designed and manufactured flex circuit can withstand hundreds of millions of flex cycles. Single-sided flex circuits have fewer processing steps and shorter manufacturing cycle times, can utilize less costly materials, and still provide the desired performance characteristics. These circuits have experienced tremendous growth in the electronic and appliance markets where high volume, repeatable process controls, and low cost are the driving factors.

Double-sided circuits carry more signals through more conductors per unit area. The double-sided flex circuit is comprised of a layer of dielectric material with copper foil laminated on each side. After conductors are formed, a cover layer of insulating material is laminated to both sides to encapsulate the traces. The double-sided flex circuit has been widely accepted by computer and automotive industries because of its mechanical flexibility, package size reduction, superior thermal properties, alternative forms, and chemical resistivity. The introduction of flexible solder masks or coverlays has significantly advanced the competitiveness of double-sided flex circuits in markets requiring high-volume, short-cycle producibility.

Multi-layer flexible circuits, which meet complex, highly populated design requirements, usually consist of several layers of copper foil and Kapton dielectric laminated together with an acrylic adhesive or a modified epoxy. They can consist entirely of flexible layers, flexible internal layers with rigid Printed Circuit Board outer layers, or flexible layers that are unbonded in bend areas. Interconnections between layers are made with plated-through holes in a manner similar to rigid Printed Circuit Board processing. Alternate multi-layer board constructions may consist of flex layers laminated together, or with one or both sides laminated with rigidized FR-4 or G-1 areas with plated-through holes. Aided by newly developed adhesiveless flex materials, multi-layer board flex technologies, originally developed for the military, are currently being used in various commercial applications.

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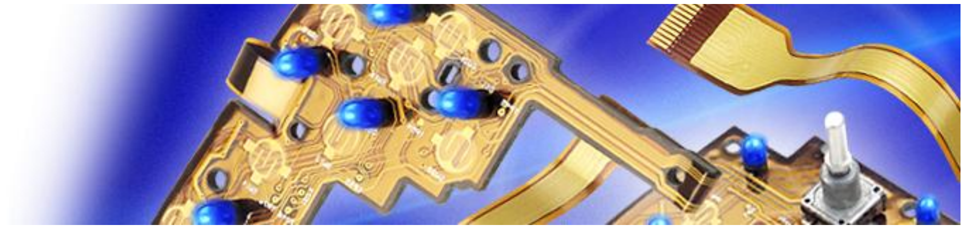

# Design Criteria

Reliability and electrical, mechanical, and environmental performance must be addressed in selecting single-sided, double-sided, or multi-layer board flex. Within these constraints, designing for manufacturability requires minimizing the overall size of the circuit, maximizing panel use, and processing the fewest possible layers. Cost cannot be ignored. If installed cost is kept in mind as the long-term goal, flex circuitry is extremely competitive.

Increasing flex requirements include shielding and electromagnetic interference (EMI), controlled and matched impedance, as well as strip-line, dual strip-line, and microstrip circuit geometry's. These demands, along with circuit dimensions and flexural fatigue endurance have prompted a search for mechanical and electrical solutions not found in conventional approaches or textbooks.

Printed circuit signal control and isolation are not new to the rigid board industry, whose designers are well versed in accommodating varying configurations--as long as the interconnects lay flat and have a one dimensional plane. Their designs are rarely applicable to three-dimensional flexible printed circuit boards. Additional copper and dielectric layers that increase circuit thickness have traditionally modified rigid and flex circuits requiring shielding. This conventional approach can double and even triple the thicknesses of a flex printed circuit interconnect. And with flex, the additional copper and dielectric layers may satisfy all the electrical requirements, but create a myriad of mechanical and reliability problems.

Additional thickness is particularly troublesome in flex installations requiring cyclic flexing over an extended period of time. An example of this requirement is the flex circuit hinge connecting the display with the driver of a laptop computer. Increased circuit thickness can displace copper traces from their most reliable position, the neutral axis, causing mechanical degradation from repeated compression and tension of the traces. The problem poses the challenge of providing additional shielding without adding copper, dielectric or cost, while still satisfying performance requirements. Additional copper and dielectric layers are also designed into circuits in order to achieve required impedance and dB isolation characteristics. In this case, the added material severely limits applications to those not requiring tight radii or sharp bends. A Parlex Corporation process called HSI+ (high speed interconnect) has resolved a variety of flexible circuit interconnect issues. Through automated screening techniques, the HSI+ shielding process applies various types of conductive materials, such as silver or copper epoxy, in specific patterns that achieve effective shielding and impedance control while minimizing circuit thickness and maximizing flexibility. The crosshatched configuration (Figure 1) allows for higher impedance values by including air as part of the plane. EMI is also addressed by the crosshatched pattern, which minimizes the effective length of each window opening. The impedance-matching shielding technology achieves cost efficiency by reducing layer count. In one case, a three-layer flex design was reduced to double-sided plated through-hole circuitry, cutting thickness by 30% and increasing flexural endurance by 37%. In another instance, HSI+ converted a three-layer design to single-sided circuit produced at a cost that was 47% lower than the original.

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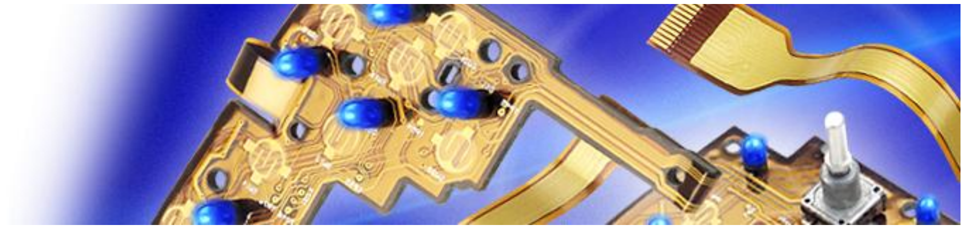

# Flex Design Guidelines

In today's robust market, the demand for flexible interconnects is increasing steadily. Early partnering with a flex manufacturer and understanding design considerations and guidelines enhance the production of a superior interconnects. Prior to designing flex circuitry, the designer must be cognizant of trade-offs in performance, reliability, cost, and manufacturability. Particularly for first-time flex designers, the following steps are highly recommended:

- Utilize industry literature to build a foundation of flex capabilities, options, and design constraints.
- Assess the capabilities differentiating flex manufacturers by reading company literature and data sheets.
- Schedule plant tours of several facilities. Question the engineering capabilities and experience in solving problems at each site. Examine quality, process control, and documentation systems. Verify the training and involvement of each work force in regard to product and quality knowledge. Compare the goals and technology roadmaps of each facility with those of the end-user.
- Once a flex manufacturer has been selected, they should be involved early in the design process. Their expertise should be drawn upon for flex design parameters to enhance manufacturability.
- Understand end product requirements and usage clearly, thus maximizing performance, reliability, and cost goals.
- Utilize the manufacturer's prototype capabilities to pilot test modifications and improvements.
- Establish strong communication links through every step of the process.

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