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DFM Analysis for Flex and Rigid-flex Design, Part 1

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Introduction

Flex and rigid-flex PCB constructions are not new concepts. It has become commonplace as engineers look for alternative circuit packaging for ever-shrinking electronic products. A flat, one-sheet schematic for a straight ribbon cable is analogous to its physical flat substrate. A flat, multi-sheet schematic that details circuitry for a rigid-flex design bears little visual resemblance to its three-dimensional, variable material rigid-flex assembly. However, in both schematic examples, schematic-based analysis tools are applied equally. This same truth also applies to common FR-4-based two-layer or multilayer PCBs.

Today's PCB analysis tools are applicable across all combinations of rigid PCBs regardless of layer count or size. However, due to the unique properties of flexible substrates and combined flexible and rigid substrates, flexible designs require a specific collection of analysis both functional and manufacture oriented.

Signal integrity analysis such as impedance, coupling, crosstalk and noise is complicated by variable stackups across flexible designs. A single transmission line can be stripline in a rigid-flex area and microstrip in a flex area. Material types and dielectric constants above or below a trace as it traverses a design also vary. While the challenges for signal integrity analysis for flexible designs is worthy of conversation, this article will focus on the current challenges to design-for-manufacture analysis of flex and rigid-flex designs.

Contrasting Rigid PCBs With Flex and Rigid-flex

Some designers design flexible PCBs as simple bendable circuit boards, but there are vast differences between rigid and flexible. Both technologies produce an electrical interconnect function, but are manufactured using different types of materials and processes. They also have varying applications. No need to design a rigid-flexible PCB for the motherboard of a desktop PC, but rigid-flex is required for most medically implanted devices.

A typical rigid PCB is comprised of electrodeposited copper-clad fiberglass substrates bonded together. While there are variations on materials used to bond substrates, it is commonly sheets of cloth pre-impregnated with uncured epoxy. This bonding material composition is not engineered to be flexible. The copper is chemically etched to create a circuit pattern. The hardness of the bonded substrates requires mechanical routing to trim the raw PCBs. All layers of the PCB are commonly identical in size and shape unless cavities, embedded components, or other such exotic construction is present. The rigid PCB layer stackup is identical across the entire PCB area. Solder mask and legend are almost always applied.

Flexible PCBs are comprised of rolled annealed copper over flexible polyimide substrates. Flexible layers or cores are produced with or without adhesives. Adhesiveless flex is prevalent in applications requiring higher performance, while those with adhesives are often found in low layer-count applications. The most common usage is copper foil laminated to a substrate with epoxy or acrylic adhesive. Both substrate material and adhesive are engineered for bending to minimize trace fracture. Like rigid PCBs, a chemical etching process is used to create a circuit pattern. The flexible nature of the materials requires die cutting or "blanking" rather than mechanical routing. Each layer of a flexible double-

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sided core has an identical shape. However, multiple-layer flex is likely to have variations in shape for each layer or core. Flexible PCBs require a thin film insulator over the conductors know as a coverlay. Unlike rigid PCB solder masks, coverlays are die cut much like the flexible layers they insulate. The stackup of a multi-layer flexible PCB can vary across the PCB area. This is especially true with multilayer flex where layer shape varies among the collection of layers or cores. A flexible ground or power plane area is typically crosshatched versus solid for rigid PCBs. The crosshatch reduces potential for fracture of conductors. Alternatively, flexible layers can be shielded with a layer of copper or silver foil. Masking and screening over flexible layers is not rare, but uncommon.

Rigid-flex PCBs are obviously a combination of rigid and flexible materials. Rigid-flex is, in essence, a hybrid PCB combination of materials and processes from both rigid and flexible PCBs. The two material types are generally processed separately and bonded together later in the fabrication process. The layer stackup commonly varies greatly across the entire PCB. There may be areas of rigid-flex, flex only, various combinations of rigid and flex layer count, and so on.

There is also rigidized flex where blank FR-4 or other rigid materials are selectively bonded to flexible substrates to provide stiffness. The rigid stiffener material rarely has conductors present.

Rigid vs. Flex and Rigid-flex

Rigid PCBs are a foundational technology in today's electronic products. Rigid PCBs offer mechanical integrity, electrical conductivity and reliability, but are limited by their two-dimensional profile. Their flatness limits designers to two dimensions which severely limits design flexibility, especially as electronic devices decrease in size. Flexible PCBs are bent to take advantage of a three-dimensional space, while also accommodating components. Flexible PCBs enable maximal utilization of space to package electronics but at a premium cost compared to conventional PCBs.

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Rigid and flexible PCBs are present in many electronic products. However, some applications benefit more from one type of circuit board. Rigid PCBs make sense for products such as televisions, desktop PCs, Blu-ray players, and other larger electronic products. Flexible PCBs are present in smartphones, smart watches, tablets, cameras, printers, and laptops. They are a fundamental requirement for implanted miniature medical devices such as pacemakers, cochlear implants, and implanted defibrillators. Complex multi-PCB assemblies interconnected with wires or cabling are often redesigned with rigid-flex PCBs to improve reliability and reduce weight and space. This is the catalyst for many military and aerospace products being designed with rigid-flex. One example is a single-use smart bullet that can change its trajectory if its intended target moves.

The introduction of small-outline and surface mounted semiconductors ushered in a revolution of miniature repackaging. Think Sony Walkman vs. a typical boom box. For years, flexible PCBs were relegated exclusively to replacement of multi-wire cables. Who would not recall the presence of a flexible flat cable connected to the head of a dot matrix or impact printer. The head would bob back and forth across the paper while the cable dynamically flexed and provided a more reliable interconnect between printer head and motherboard.

The introduction of rigid-flex was not quite the same level of game-changer as surface mounted packages due to its somewhat limited application and cost differential. We shouldn't expect a new collection of desktop PCs to be designed with rigid-flex motherboards as a means to reduce cost. However, miniaturized and reliable technology such as pill cameras, foldable cellphones or implanted medical devices would not exist without rigid-flex technology.

We'll pick this up this discussion with Part 2 in the next issue of *Design007 Magazine*. **DESIGN007**

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