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## Rigid-Flex

### Hitting the Mainstream Bull's-Eye

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By Mark Finstad

# Driving Costs for Flex Circuits

**Q:** ***Why are flex circuits more expensive than comparable rigid PCBs? What are the major cost drivers for flex circuitry?***

**A:** The reason that flex circuits cost more than comparable rigid PCBs stems mainly from the materials used to fabricate the circuits. First of all, flex materials (i.e., clad and unclad polyimide film with or without acrylic adhesive) can cost two to three times more than similar rigid-based materials. But the raw material costs only account for around 25 percent of the final circuit cost. Flex materials are much more difficult to process than rigid PCB materials, and this is where most of the cost difference comes from. Typically, flexible copper clad base materials have substrates that are only 0.002 to 0.003 in thick. Because flexible base materials are so thin, they are also extremely fragile and very prone to damage during processing. Any mishandling of the material prior to the photo-etch process can cause a dent or wrinkle, which in turn can cause an etch flaw. Another material aspect that impacts circuit yields is lack of glass reinforcement in the material. Virtually all materials used to fabricate flex circuits are non-reinforced film based. This lack of reinforcement makes flex circuit materials dimensionally unstable. Manufacturing, temperature, and humidity can cause stretching or shrinking of the different layers, and the stretching and shrinking is not consistent from layer to layer. Circuit layers that have high copper content (e.g., plane layers) will be affected much less than signal layers where over 50 percent of the copper is removed. Now consider trying to stack up 0.030 in pads on an eight-layer circuit where half of the layers have shrunk and the other half stretched. Most flex circuit manufacturers have learned to predict what the different circuit layers will do during processing and compensate artwork to reduce the impact of these dimensional changes. But this is far from an exact science, and many times the first fabrication run ends up in the scrap barrel and additional tweaking must be performed on the artwork. All of these costs are rolled into the price the customer pays for the flex circuit.

The cost of flex circuits are driven mainly by layer count and the physical size and shape of the circuit. Many other features also have an impact on the final cost, but these two items are usually responsible for 75 percent of the cost. Most flexible circuits are manufactured in panel form and then are removed from the panel prior to being shipped to the customer. Each panel costs the manufacturer a certain amount to process based on the materials used, layer count, and complexity. That cost is divided by the number of parts per panels to give the final circuit cost. Obviously, the more parts the manufacturer can squeeze on the panel, the lower the cost per circuit. Also, any feature of the circuit that decreases panel density can have a big effect on the circuit cost. For example, if you have a roughly square flex circuit that is 5 in per side and it is built on a 12 x 24 in panel, the panel would hold eight circuits. Now, if you were to add a small appendage to one side of the circuit that is about one-fourth in wide and 2 in long, you would reduce the number of circuits per panel by 25 percent. That little appendage effectively added more than 30 percent to the cost of the flex circuit (see Figure 1). This is one reason that it is important to include the manufacturer during the design process so that seemingly inconsequential features like this can be flagged and possibly modified.

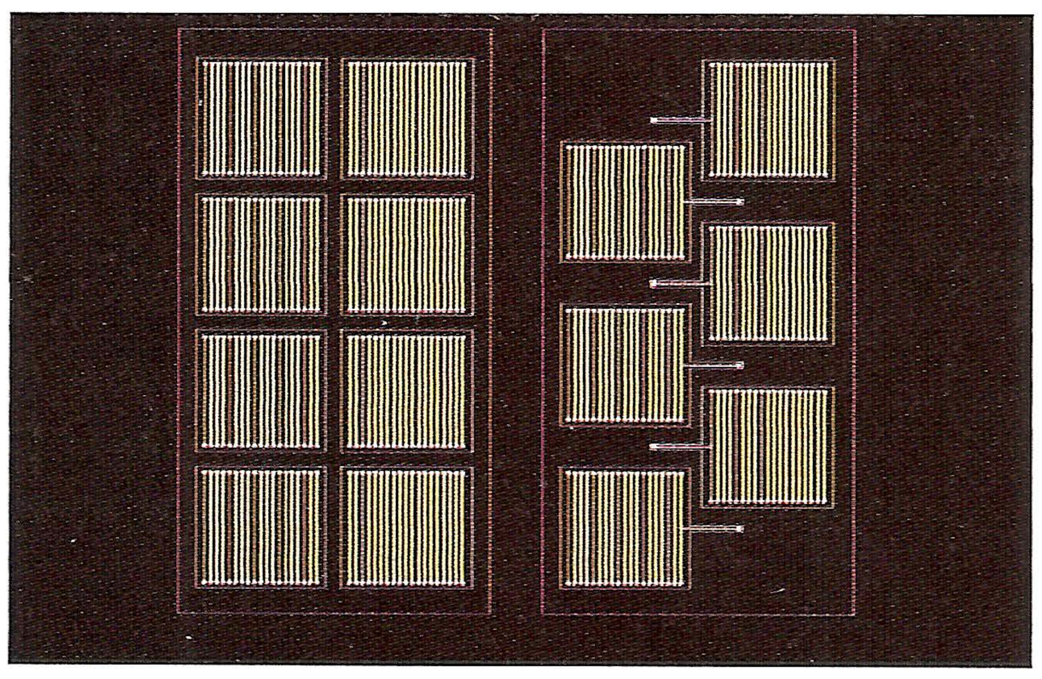

**Figure 1 Left Panel Shows a Circuit Shape That Can Be Efficiently Nested on the Panel for Optimum Use of Space, Which Results in a Lower Cost. Circuits on the Right Panel Have a Small Appendage That Significantly Reduces the Panel Density and Increases the Cost**

The circuit layer count is the other big cost driver of flex circuitry. As the number of circuit layers increases, the processing issues associated with the dimensional instability of the materials have a bigger effect on the manufacturing yields. As yields drop, costs increase. Just a few of the processing issues that are complicated by a high layer count are layer-to-layer alignment, plated through-hole integrity, thermal expansion in the z axis, and lamination defects. Also, as the layer count increases, internal etch yield has to be at or very near 100 percent. This means that inner layers with even a few etch rejects must be discarded prior to layer lay up. The cost of these discarded inner layers is amortized into the final circuit cost.

If cost is a key concern (and when isn't it?), consider the material requirements and do not over-spec. For example, consider a PET/polyester laminate over polyimide if your process window will allow for lower temp processing. RoHS requirements drive the need for higher temperature processing but "simple" flexes can take advantage of less costly lower temperature materials.

It is important to keep in mind, however, that cost, while important, should take a back seat to value. Moreover, cost both "in the front door" and "out the back door" need to be considered when doing a true value analysis, as a flex circuit might greatly improve some attribute of the design in terms of other material or labor savings. Accounting systems can tell one the price of everything but they say nothing of the value and benefit that is extracted by using a more costly solution.

The Flexperts are Mark Finstad and Mark Verbrugge