Rigid-Flex Technology: Mainstream Use but More Complex Designs

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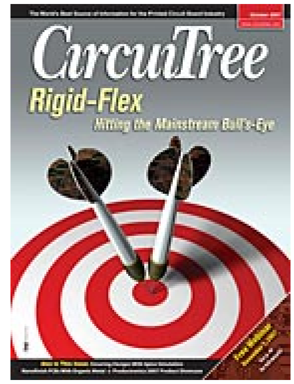

In the past, flex and rigid-flex technology was typically used in applications that could tolerate long design times. Today, with the rapid increase of flex in consumer products, the design of these products must be highly automated to achieve the short time-to-market targets of the electronics company. However, this design process can be very complex, involving not only typical PCB placement and routing but very specialized manufacturing considerations, three-dimensional interference checking, and complex high-speed design and analysis. This article will discuss the emerging uses of rigid-flex technology, its strengths and limitations, and special design issues.

Rigid-Flex Technology

Rather than limit their thinking to two-dimensional space containment for PCB implementations, circuit designers, package designers, and manufacturing engineers have been collaborating to make the best possible use of every square inch of today's small and innovative product packages. This has increased the demand for what was once a more specialty PCB design, that is, combining rigid PCBs with flexible elements, all of which are laminated together into a single, rugged, three-dimensional rigid-flex PCB. By thinking in three-dimensional space, designers can fold, twist, roll, or manipulate the circuit into any number of special transformations to achieve the optimal shape to fit the final product package.

These types of rigid-flex PCBs are not simply boards with flexible ribbon cables connecting them, such as printer heads on inkjet printers—those cables are designed to be in constant flex over time. Rigid-flex refers to a rigid board with flexible substrates that are bent when manufactured, or designed as flex-to-install. Rigid-flex PCBs incorporate multiple layers of both rigid and flexible layers. These can take advantage of all the latest PCB synthesis and manufacturing techniques, including multiple layers, because they are not constantly flexed. However, there are additional challenges to designing and building rigid-flex boards compared to standard rigid boards.

Applications for Rigid-Flex

There are a number of applications where either the cost for rigid-flex PCBs is acceptable or must be absorbed because the specific product package requires rigid-flex to allow the component density in the allowable space. In each of these cases, rigid-flex techniques provide the solution if certain design and manufacturing issues are confronted early, as described in the next section. As understanding of rigid-flex design and manufacture has progressed, rigid-flex PCBs have become more of a mainstream product than a highly specialized solution.

Applications for rigid-flex range from high-end, high-performance military weapons guidance systems to inexpensive consumer products such as cell phones, smart toys, multimedia players, and digital cameras. Another extremely active application area is medical products. Rigid-flex not only allows electronic circuits to occupy considerably less volume than traditional rigid boards, but it reduces the overall product weight. This makes the technology extremely useful in medical implants such as pacemakers and cochlear implants. Being able to fold the circuit board in intricate ways to fit inside these implants reduces weight and significantly improves reliability. Thus, in the long run, the cost differential is absorbed by better reliability and lower warranty cost.

The same reduction in failure associated with rigid-flex solutions and lower weight makes the technology especially suited to military applications. An example such as weapons guidance systems makes this clear. Every ounce of weight reduces the payload and/or fuel that can be carried—both critical components of the system. Weight reduction when switching from traditional to rigid-flex PCBs has measured as much as 90 percent. And military requirements for reliability are as stringent and important as life-dependent medical devices.

Consumer products have been adopting rigid-flex technology at a growing rate. As this adoption infiltrates the consumer product market, the cost floor when considering rigid-flex has continued to become lower and lower. An important factor in consumer products that is not as critical in medical and military applications is the attractiveness of the finished product. With ever-increasing complex product appearance designs, interior volume, traditional rectangular spaces, and intricate routing of wiring to switches and I/O devices have virtually dictated use of rigid-flex for a number of these designs. With rigid-flex, the same benefits of weight reduction and increased reliability are important, but additional benefits such as intricate signal routing without fragile wires or solder joints, integrating battery connections, and fitting much more circuitry than ever possible within shrinking volumes make it an attractive option.

There are, of course, many other application areas as well. Test equipment, portable electronic tools, and automotive applications are other areas that fit rigid-flex's advantages. Any design that can exploit the benefits detailed in the preceding is worth an analysis to determine if rigid-flex is a viable option.

More Demanding Design and Manufacture

Rigid-flex PCBs are more demanding to design and manufacture. Figure 1 shows a typical, four-layer rigid-flex board. The core of the assembly is a flexible polyimide substrate with copper foil (represented in red) bonded to each side. This is covered with a top and bottom polyimide film that is cemented with a thin layer of acrylic adhesive. Next, the outer, rigid FR-4 PCB blanks are laminated to this core with a no-flow prepreg layer between the FR-4 and the flexible substrate.

The flexible components of the PCB must be handled, etched, and soldered differently than the rigid components. At the material interface, they must be laminated, drilled, and plated. Clearly this adds up to increased manufacturing time and cost. It also requires additional design time to accommodate the multiple material demands. The bottom line is that rigid-flex PCBs cost about five times that of traditional boards.

Begin PCB Design Earlier in the Design Phase

The differences in the type of materials used and the more difficult fabrication involved in making rigid-flex PCBs requires more time than a traditional board, so the decision to use rigid-flex must be made early in the design phase and the process begun in time to deal with the requisite additional design time. It takes more effort than simply using PCB designs created for rigid PCBs. For this reason, it is also a good idea to bring the PCB fabrication house into the design as early as possible. Good houses have worked with rigid-flex before and understand the materials and characteristics quite well.

Fabrication House Selection

Perhaps the most important criterion when selecting a PCB fabrication house for a rigid-flex board is that the house has previous experience with rigid-flex. Most houses understand the different rigors associated with rigid-flex fabrication and can accurately predict material movement and shrinkage, thereby producing a finished product that is as close to dimensional tolerance as possible. This allows the mechanical PCB fabrication processes such as drilling and routing to proceed as normal. Because of the more intense design and fabrication required for rigid-flex, bringing in the PCB fabricator early in the design is a good idea.

Rigid-Flex Design Issues

Different materials behave differently during manufacture. The flexible polyimide core shrinks considerably when the copper has been etched away. Failure to account for dimensional variability will result in a lot of headaches and last-minute corrections to the design.

- To deal with these dimensional differences, the following suggestions can be considered:
- Increase the minimum annular ring for all plated through-holes on flexible layers;
- Ensure all trace-to-pad junctions have teardrops;
- Ensure all trace-to-trace junctions have teardrops; and
- If connecting islands of the rigid PCB to the inner flexible layers, the rigid areas must be supported during fabrication, as these must be removed to expose the flexible layers below. Figure 2 illustrates this process.

Typically, the flexible layers are die cut, as this is the best way to cut thin polyimide material. Parts of the flexible layers might need to be removed, which may require areas that can have no component placement or routing or may require special care to prevent components or traces from hanging over the edge of a rigid area, which could interfere with folding in the final assembly. Each of these considerations must be accounted for when in the design tools. Figure 3 shows the final routing path on an example layout.

Final assembly requires that the assembly be bent into the final shape. This action puts additional stress on the laminations and traces on the flexible portion of the assembly. It's imperative that the design reduces the potential of stress fractures occurring due to this stress. Here are some design considerations to minimize stress fractures:

- Route traces through a bend area perpendicular to the bend axis;
- Keep trace corners, width changes, and vias away from the bend area;
- Use crosshatched areas of copper fill (not solid); and
- Stagger adjacent layer parallel routing. Figure 4 illustrates this technique.

Greater Automation With EDA Tools

Another key to exploiting rigid-flex with reasonable cost containment involves using as much automation as possible when designing the PCB. A number of tools are available that make design simpler and reduce overall cost when designing a rigid-flex board.

Because of dissimilar materials used in rigid-flex assemblies, different physical properties, and other design and associated fabrication challenges, rigid-flex designs require more complex design rules; in the past, the only way to handle these rules was by manual editing. This is, of course, time consuming and expensive, as well as an increased opportunity for errors.

Newer tools incorporate these increasingly complex rules and provide significantly more automation when designing rigid-flex boards. For example, some products have placement and routing environments that encompass the definition and checking of complex rules for rigid-flex designs while maintaining high productivity. Among the rules that are specific or more complex with rigid-flex design are curved trace settings by area to accommodate the different material properties; complex contour following for routes; teardrops at pins; t-junctions and route width changes; cross-hatching shielding areas; and selective pad modifications.

Tools can also work with the issues described in the preceding sections, such as minimizing contact with router bits, three-dimensional interference checking for components, proper material stretch and shrinkage parameters, and other reliability-enhancing capabilities.

Coupling these tools with existing EDA tools allows designers to conceive the complex rigid-flex shapes while still maintaining product reliability after considerable bending. Without tools that readily accommodate rigid-flex rule sets, many designs could not be possible within the product design budget.

Conclusion

Rigid-flex PCB technology has often been perceived as too expensive to use except where there is no other solution for fitting a circuit within a particularly constraining enclosure, or the weight and reliability benefits are paramount to the end product. This is especially true in longtime rigid-flex applications such as the military, aerospace, and medical device markets.

However, increased use of the technology coupled with automation capability of PCB design tools has begun to make use of rigid-flex in mainstream applications more amenable. This has resulted in rigid-flex technology appearing more frequently in mainstream products, especially when the package design is unusual and constrains the physical space available for electronic circuitry. This trend indicates that rigid-flex PCB technology is viable for mainstream uses that it bears investigation whenever a new product design is undertaken.

Once the decision has been made to incorporate rigid-flex PCBs, the fabricator should be involved as early as possible. Selecting a fabricator that has experience with rigid-flex should be a top requirement. The fabricator can be invaluable in eliminating possibility for error or problems early on in the design. Using an experienced fabricator along with EDA tools that easily handle rigid-flex increased complexity rules is the best combination for a high-quality, easy-to-use rigid-flex PCB design.