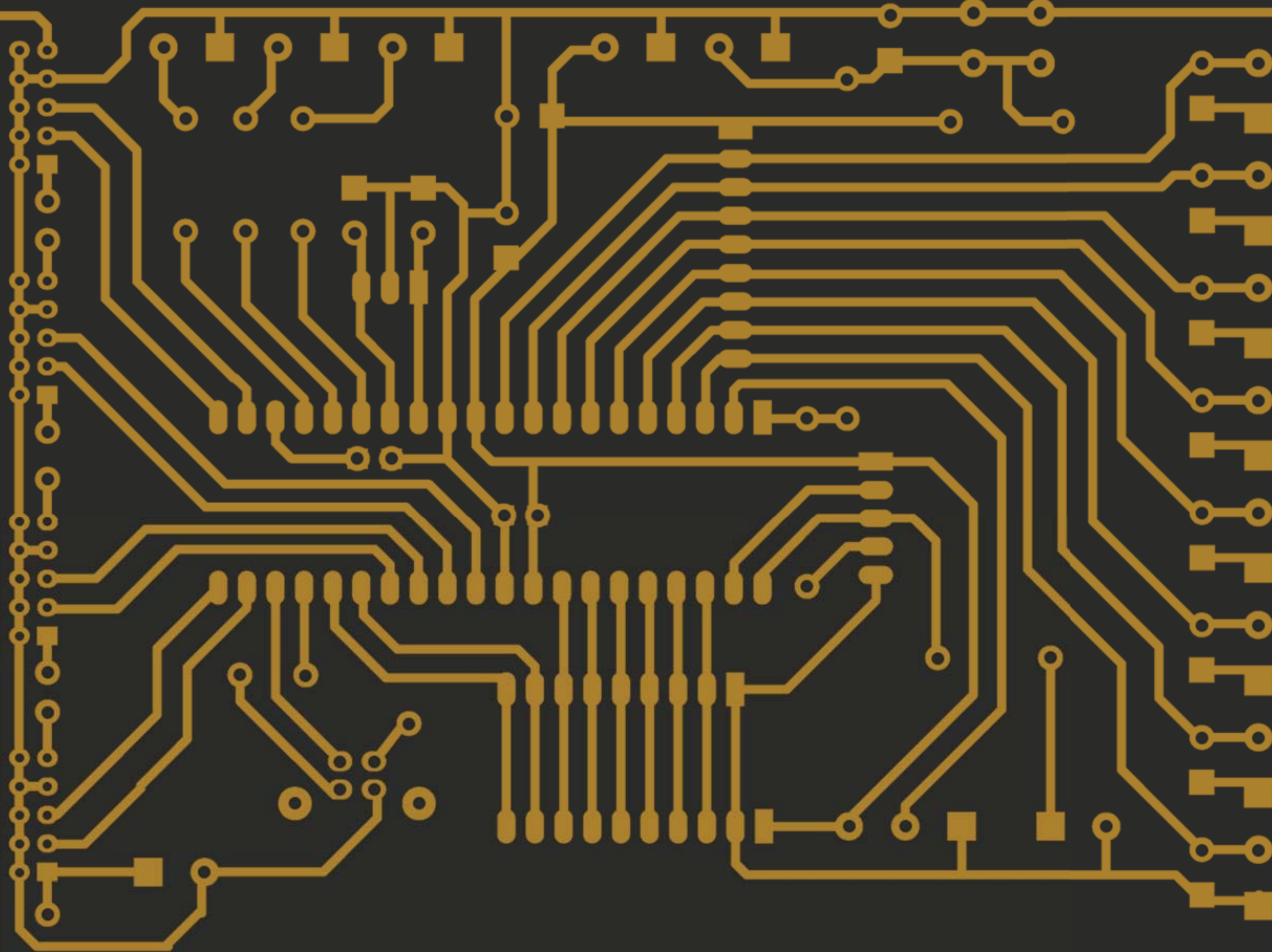
Altium

Meeting the Challenges of Wearable Devices with Rigid-Flex PCB Design



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There is no question that wearable electronic devices qualify as "break-out products". The market for wearables is forecasted to be $30 billion in 2016 and will grow to be $150 billion by 2026[1]. Most of these devices are simply impossible to design without rigid-flex PCB technology. This means that engineers and PCB designers need to become experts in designing, testing, and manufacturing in a wearable and "foldable" world.

The most familiar products are probably smart watches that link with smartphones, and fitness trackers that are also worn on the wrist. But beyond these consumer products, wearables have made huge inroads into medical devices and military applications. Now, smart clothing is appearing that could virtually eliminate the possibility of incorporating rigid PCBs. This paper will explore what makes wearables unique, and what is needed to successfully design flex and rigid-flex PCBs.

COMPLEX FEATURES MEAN COMPLEX PCBS

It goes without saying that a wearable device has to be small and virtually unnoticeable to the wearer. In the case of medical wearables, users usually don't want them to be noticed by others either. Not that long ago, "wearable medical devices" were fairly large and often required a belt mount or shoulder strap.

Today, wearables are everywhere, with wristwatch-style fitness trackers becoming one of the leading wearable products. These devices use sensors to monitor several parameters and calculate various fitness-related parameters. But they are very tiny for such sophistication, requiring flexible PCB techniques. Smart watches provide designers a bit more space, but with the increased complexity of features this real estate quickly becomes consumed.

Wearable medical devices have evolved into small, unobtrusive "patches" that the user wears to monitor a particular area of anatomy. They are totally self-contained with electrodes, adhesive, rechargeable battery, and intelligence with a small footprint, such as the one in Figure 1.

Figure 1: Wearable medical devices have evolved to little more than a bandage size, yet they incorporate a great deal of intelligence and memory. Devices such as this make considerable use of 3D, rigid-flex PCBs. Photo courtesy of MC10, Inc.

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DESIGNING RIGID-FLEX PCBS

Wearable devices that attach to the human body in one way or another dictates flex circuitry and very dense layouts. Not only that, but board shapes are often round, elliptical or even more unusual shapes. From a designer's point of view these projects call for clever placement and routing. For such small and densely-packed boards, a PCB tool that is optimized for rigid-flex designs makes handling odd shapes much easier.

The majority of PCBs designed today are basically rigid plates to connect circuitry. But, wearable devices present a number of difficulties for PCB designers that rigid boards do not. Here are some of those problems and what designers can do to alleviate them.

Three-Dimensional Design

One of the primary advantages to a rigid-flex design is the ability to fold the flex circuits any way necessary to make the electronics fit inside a three-dimensional space. The flexible circuits let the entire assembly be bent and folded to conform to the package. Figure 2 shows a typical rigid-flex product. Three rigid boards are connected together by flexible circuitry. The flexible circuitry is then bent to allow the rigid PCBs fit into the product package while occupying minimal space.

Figure 2: Typically, rigid-flex has the components mounted to rigid boards interconnected by flex circuits. The flex circuits let the assembly bend to fit the assembly into the product enclosure.

There are a lot more challenges in rigid-flex designs than just connecting rigid boards. Bends must be precisely designed so boards line up where they are intended to mount without putting stress on connection points. Until recently, engineers actually used “paper doll” models to simulate the PCB assembly. Now, design tools are available that provide 3D modelling of the rigid-flex assembly, allowing quicker design and much greater accuracy, as shown in Figure 3.

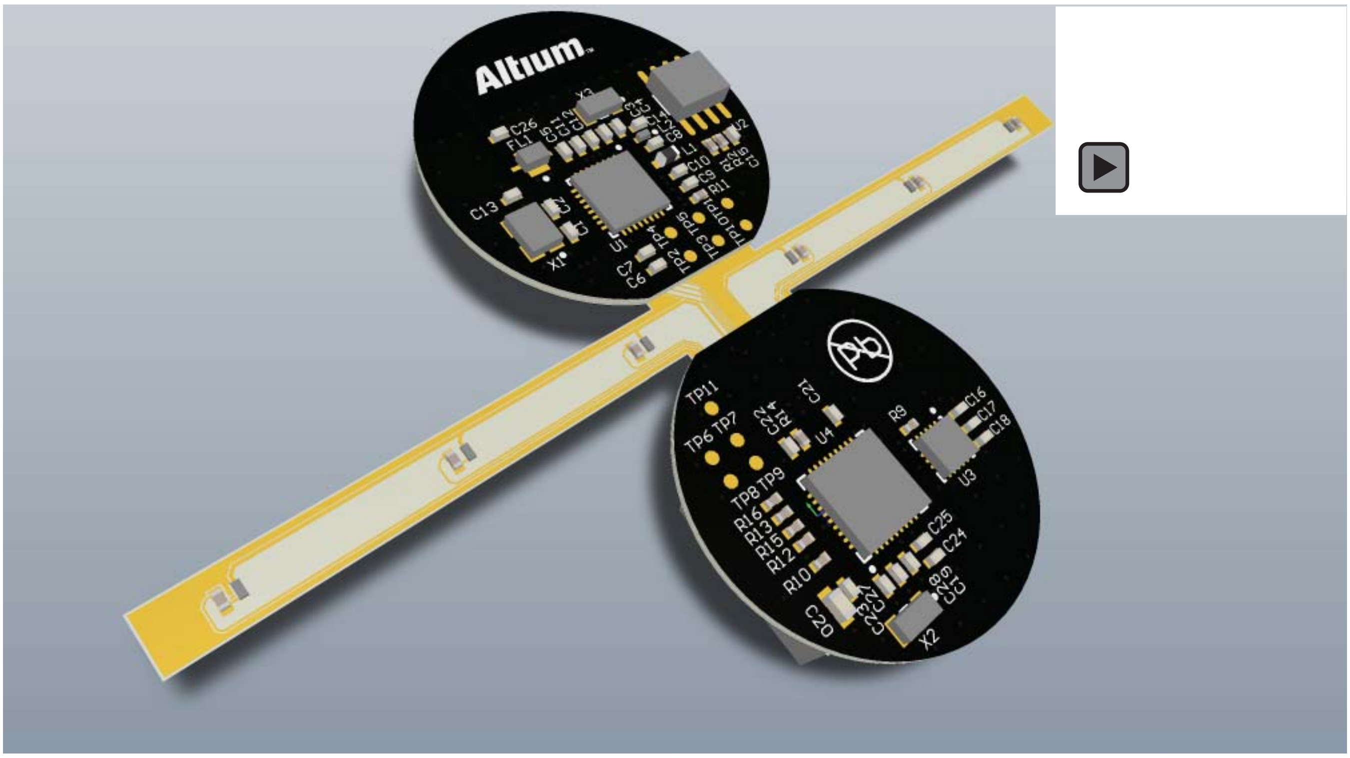

Figure 3: PCB design software that provides 3D modelling lets designers see exactly how the PCB assembly fi ts together.

Rigid-to-Flex Stackup Design

The PCB stackup is a map of the layers of a printed circuit board. The stackup is critical for any PCB design, but even more so when designing with rigid-flex techniques. The best PCB design tools for rigid-flex let you design your stackup with both the rigid and the flexible parts of the assembly integrated — just as the final product will be. With flexible circuitry, the bending area should be designed to minimize stress on the traces and pads.

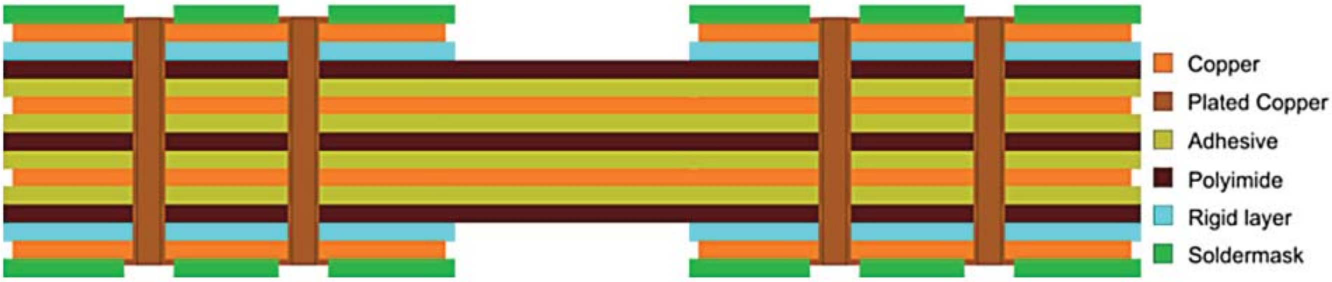

Figure 4: PCB design software should let you work with the entire assembly. Here, the rigid PCBs are on either end, connected by a two-layer flexible circuit.

A full stackup, with rigid boards on the left and right and flex in between, is shown in Figure 4. The number of layers and materials used for those layers add complexity to the design. That makes it very important to carefully design the stackup with PCB software that can handle the entire flex and rigid assemblies.

Handling the Flex-Circuit Bend

The capability to shape the final assembly of rigid and flexible PCBs to fit a product enclosure is the primary advantage of flexible circuitry. Of course, that gives you a number of issues not encountered on rigid PCBs, as bending the flex circuitry produces stresses that do not occur with rigid boards.

Here are four tips to incorporate in your next rigid-flex design project:

1. **Increase trace reliability:** The bending that flex circuits endure means that the copper is more likely to delaminate than on a rigid board. The adhesion of copper to the substrate is less than on an FR4 PCB as well. Most board manufacturers recommend using through-hole plating and anchor stubs for SMT mounting pads and reducing coverlay openings as much as possible.

2. **Strengthen traces and vias with teardrops:** If not controlled, bending the substrate can lead to delamination and product failure. Traces and vias can, however, be strengthened to prevent delamination. Substitute teardrop pads (Figure 5) for circular pads. Teardrops add additional material, strengthening the pad to prevent delamination. Using teardrops can also produce better yield in manufacturing by giving more drilling tolerance.

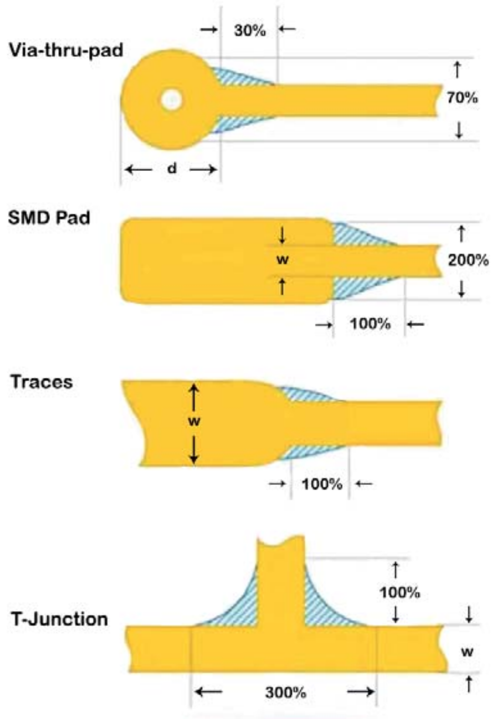

Figure 5: Teardrops increase trace strength and improve the yield.

3. **Offset traces on double-sided flex circuits:** Lining up traces on top of each other on double-sided flex circuits can cause problems with distribution of the tension, particularly at the bend. To even out stresses, as well as add more flexibility, offset the traces on two-sided flex circuit.

4. **Avoid right angles on traces:** Trace corners are subject to more bending stress than straight paths. Over time, the corners can delaminate, causing product failure. Avoid delamination problems by using straight paths. When traces must change directions, use curves or piecewise-linear curves rather than anything approaching 90°.

FABRICATION

Qualifying multiple fabricators is a requirement at most companies, but qualifying rigid-flex fabricators is a bit more difficult than standard rigid PCB fabs. Doing the homework to evaluate fabricators, and clearly communicating design expectations are the keys to ensure that your rigid-flex assembly will be properly manufactured.

The best way to approach fabrication is to consider it from the inception of the design. That way, you can communicate with them to ensure your design is consistent with their requirements at all times during the design. You can also incorporate their requirements into design for manufacturing (DFM) and design rule checking (DRC) processes that you use. Most importantly, make use of design standards, such as IPC-2223, to communicate with your fabricators.

The finished design data package must be assembled for hand-off to your fabricator. Gerber formats can work for rigid PCBs, but with the extra complexity of a rigid-flex assembly both PCB software tool vendors as well as fabricators recommend an intelligent data exchange format be used. The two most popular intelligent formats are ODB++ (version 7 or later) and IPC-2581, as they allow you to clearly specify layer requirements.

BECOME A RIGID-FLEX EXPERT

Wearables require what traditional PCBs cannot deliver: the ability to flex, stretch, and move while worn or attached to the human body. Combinations of rigid PCBs containing most or all of the components are married with flexible circuitry that can bend with the body's movement, as well as allowing designers to make their designs foldable, 3D realizations.

Designing flexible circuitry creates challenges beyond those for rigid boards. Of primary importance is the stackup design: it must be correct for function as well as long-term reliability. Because flexing puts more stress on the copper, you need to use techniques that reinforce the traces and pads to ensure adhesion. Finally, you need to be more diligent in both locating and communicating with rigid-flex fabricators.

Altium Designer® provides the most comprehensive set of tools for working with rigid-flex designs. Stackups can be fully mapped and then modeled in 3D. Teardrops and reliability enhancement techniques are simple and quick. And, you can select either ODB++ or IPC-2581 for formatting your manufacturing output data to ensure complete communications.

REFERENCES

[1] **Wearable Technology 2016-2026**; James Hayward, Dr. Guillaume Chansin, Harry Zervos; IDTechEx.

Learn More About Layer Stack Management

Learn More About Native 3D Editing

Visualizing Your Rigid-flex Design Before Going to Prototype