Quarterly | October 2018

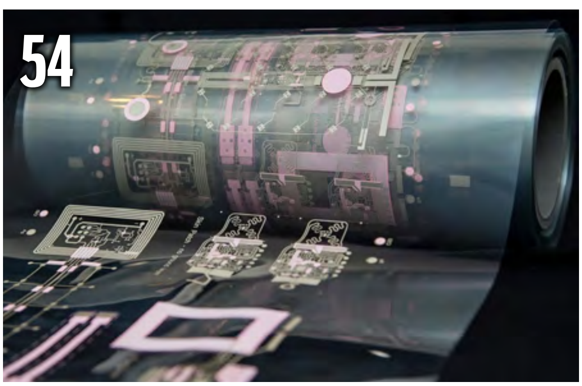
I-Connect007

FLEX007 MAGAZINE

The Journey into Rigid-Flex

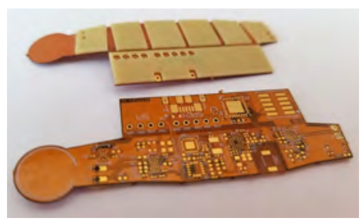

Get flex right the first time!
THE PRINTED CIRCUIT DESIGNER'S GUIDE TO...™
Flex and Rigid-Flex Fundamentals
Anaya Vardya and David Lackey
American Standard Circuits
I-007e Books
LEARN HOW TO:
• Specify suitable materials
• Identify critical requirements
• Understand the important issues
FREE PDF DOWNLOAD
OR
PRINTED ON DEMAND
I-007eBooks.com/flex
I-007e Books
I-007eBooks.com

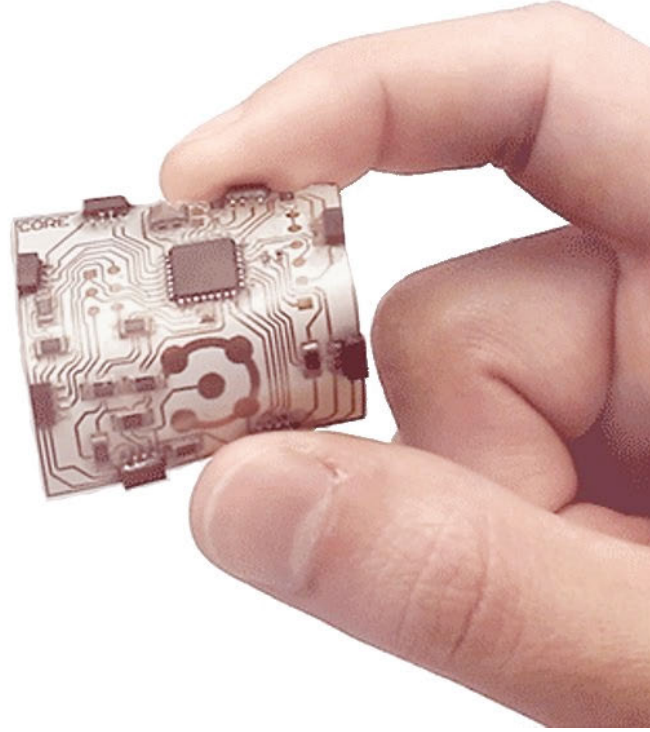
FLEX007 MAGAZINE



The Journey into Rigid-Flex

This month, we take a closer look at the ins and outs of rigid-flex from design through assembly. Our authors provide tips to help you on your journey. There are tips for everyone, whether you are interested in the design end or concerned about assembling your product.





PYRALUX® FLEXIBLE CIRCUIT MATERIALS

PYRALUX® AP
high reliability flex & multilayer circuitry

PYRALUX® AC
for thin, light, high density with chip-on-flex attachment

PYRALUX® HT
for high temp, high performance flex

PYRALUX®TK
Teflon®/Kapton®

PYRALUX® LF
industry standard for high reliability

PYRALUX® FR
flame-retardant for products requiring UL rating

PYRALUX® APR
reliable resistor, temperature tolerant

DuPont offers a comprehensive, industry-leading portfolio of Pyralux® flexible circuit materials and systems designed to meet today's and next generation design challenges.

The Pyralux® portfolio includes a diverse collection of core dielectric materials and customized dimensional constructions that enable the designer and manufacturer of complex circuits to deliver high performance solutions.

DuPont Pyralux® copper clad laminates, bondplys, coverlays, and adhesive systems offer excellent functional performance and high reliability and allow for the fabrication of thin, solderable, high density electrical interconnects for single and double-sided, multilayer flex and rigid flex applications.

FLEX007 MAGAZINE

SHORTS:

COLUMNS:

DEPARTMENTS:

Moving Right Along

ReFLEXions

by Andy Shaughnessy, I-CONNECT007

It is with a heavy heart…no, that's not good. Parting is such sweet sorrow…no, I don't like that either. Let's cut to the chase.

In a nutshell, former *PCB007 Magazine* Managing Editor Patty Goldman is now taking over *Flex007 Magazine.* I'm grateful that I've had the chance to help get the *Flex007 Magazine* off the ground. It's been a lot of work, but a lot of fun too.

I've learned quite a bit over the past year. I had no idea so many of you are either using flex or considering moving into flex. Quite a few of you now find yourselves having to learn everything you can about "flexitos," as contributing editor Kelly Dack refers to them, solely because rigid boards just won't fit in your form factor anymore, and you've just about run out of options. It's still surprising to me that flex and rigid-flex are now being considered as a high-reliability option.

I still can't believe how many everyday household items now contain flex. Not long ago, flex was too expensive to even consider; now it's easier to point out products that don't have any flex inside. IPC standards and EDA tools have largely caught up with the designers' skill, though some designers are pushing both of these to their limits with the most cutting-edge flex designs.

The best part of this whole adventure has been meeting with people in the flex segment, many of whom have shared stories about their successes and failures. I've met PCB designers who had never designed a flex circuit before, but now they're immersing themselves in flex design techniques. As usual, the designer seems to get much of the blame, rightly or wrongly, for failing flex circuits.

I've also heard some constructive advice from flex CAM departments. One CAM guy said, to paraphrase, "Designers get the electronics perfect, but then they place a fixture or connector too close to the bending region, etc. Designers need to watch out for the simple mechanical problems when they're designing flex."

Speaking of fixtures, there's one thing that almost everyone using flex can agree upon: Flex assembly is a big bottleneck. OEMs say too often that they feel like they're re-inventing the wheel during assembly. Part of this is because flex and rigid-flex are (more or less) custom products, so assembly is likely to remain a trouble spot for the near future.

Flex is one of the hottest areas in this industry, and it's only going to get hotter as 5G, IoT, and artificial intelligence start to take hold. It's going to be a wild ride, but we'll be here to make sense of it all.

As I said, I've enjoyed getting *Flex007 Magazine* up and running, but it's time for me to hand it off. I'm leaving you all in the capable hands of Patty Goldman. She'll take good care of you, and I'll still be covering flex from the design side.

See you on the road! **FLEX007**

The Journey into Rigid-Flex

Patty's Perspective

by Patty Goldman, I-CONNECT007

Hello, folks, and welcome to the third edition of our *Flex007 Magazine*. It's time to jump into something new—not totally new, but different enough to be challenging and intriguing.

I was never much for change, especially not change for the sake of change. You would find me whining, "Why do we have to do things differently? I liked the same old, same old." And of course, invariably the change would happen, I would adapt—grudgingly at first—and then I'd realize that, no kidding, it really was better. Oh, but the pain and discomfort in the meantime. Am I alone in this? I don't think so…

Here we are in the world of electronics and guess what? New things and new ways are coming at us with such speed that we don't even have time to whine before the next thing is upon us.

The Journey into Rigid-flex

This month, we take a closer look at the ins and outs of rigid-flex from design through assembly. Our authors provide tips to help you on your journey. There are tips for everyone, whether you are interested in the design end or concerned about assembling your product.

Starting our lineup is our flex philosopher, Joe Fjelstad of Verdant Electronics, with some encouraging words for those of you contemplating flex and/or rigid-flex circuits. He gives no answers but encourages you to fully investigate the "why" and "why not" questions applied to materials, vias, coverlayers and more.

With a more practical bent, Omni PCB's Tara Dunn teams up with Anaya Vardya of American Standard Circuits (ASC) to discuss not just the benefits of rigid-flex, but also how to do a realistic cost justification. They also talk about ways your fabricator can help with such things as when to use stiffeners, array design and panel utilization, and dynamic flexing.

So now you know how to justify rigid-flex, but what if you are entirely new to rigid-flex design? Turn to Printed Circuits' Bob Burns

whose experience will help you with many "pointers," such as impedance considerations, material layup considerations, rigid-to-flex transition areas, and more.

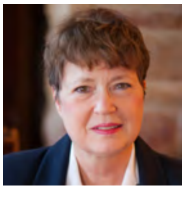
In their final installment of the three-part series of excerpts from their eBook on flex and rigid-flex fundamentals, ASC's Dave Lackey and Anaya Vardya discuss a number of special types of flex and rigid-flex circuits. Read about bookbinder construction, anchoring pads, thick copper, and high-layer-count flex and rigid-flex. Are you feeling confident now with all this great advice?

The big news at All Flex this fall is their new president and CEO, Matt Keithly. In an interview, he tells us about himself, the great culture of both All Flex and their parent company, Granite Equity, and his plans for All Flex as the Minnesota-based company moves deeper into rigid-flex.

With some additional guidelines for rigid-flex, let's turn to Tuan Tran with Green Circuits. He provides details and tips on design, manufacturing and assembly focusing especially on the intricacies of rigid-flex designs, handling issues, and the importance of baking prior to assembly.

Wrapping up this issue is a great article to help expand your thinking with the possibilities of printed electronics as applied to flex and rigid-flex. Corné Rentrop with the Holst Centre in the Netherlands helps to stretch our minds with his article on curved, flexible, stretchable, and 3D electronics. Time to think out of the (rigid) box!

And there you have it. Those of you familiar with my columns from *PCB007 Magazine* know that I usually end with an exhortation to subscribe—in this case to our newest magazine—for delivery direct to your e-mailbox as soon as the next issue is published in January when our topic will be "thinking and designing in three dimensions." See you then! **FLEX007**



Patricia Goldman is managing editor of *Flex007 Magazine*. To contact Goldman, click here.

'Robotic Skins' Turn Everyday Objects Into Robots

When you think of robotics, you likely think of something rigid, heavy, and built for a specific purpose. New "robotic skins" technology developed by Yale researchers flips that notion on its head, allowing users to animate the inanimate and turn everyday objects into robots.

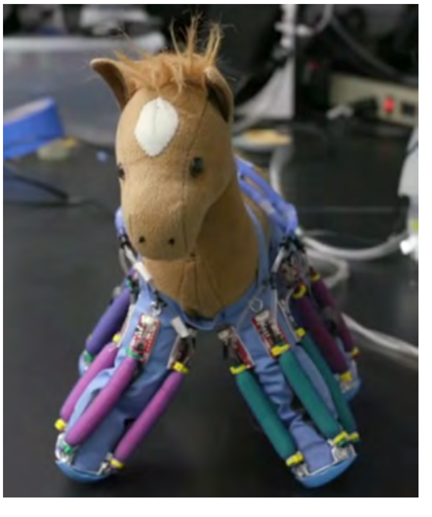
Developed in the lab of Rebecca Kramer-Bottiglio, assistant professor of mechanical engineering and materials science, robotic skins enable users to design their own robotic systems. Although the skins are designed with no specific task in mind, Kramer-Bottiglio said they could be used for everything from search-and-rescue robots to wearable technologies.

The skins are made from elastic sheets embedded with sensors and actuators developed in Kramer-Bottiglio's lab. Placed on a deformable object—a stuffed animal or a foam tube, for instance—the skins animate these objects from their surfaces. The makeshift robots can perform different tasks depending on the properties of the soft objects and how the skins are applied.

The robotic skinsallow users to create multi-functional robots on the fly. That means they can be used in settings that hadn't even been considered when they were designed, said Kramer-Bottiglio.

To demonstrate the robotic skins in action, the researchers created a handful of prototypes. These include foam cylinders that move like an inchworm, a shirt-like wearable device designed to correct poor posture, and a device with a gripper that can grasp and move objects.

(Source: Yale University)



Achieving Continuous Flexible Circuit Innovation

Flexible Thinking

by Joe Fjelstad, VERDANT ELECTRONICS

Since their introduction, flexible circuits have continued a steady climb from relative obscurity to center stage in the world of electronic interconnections. Today, they are among the most popular choice for solving challenging electronic interconnection problems. Those who use this technology on a regular basis are familiar with the many reasons for the popularity of flex.

Flex circuits are thin and light; they can be bent, folded, or flexed. When challenged, they can offer superior electrical performance due in part to the different polymers used as substrates. In short, flex circuits provide highly reliable interconnection structures that make possible solutions, which cannot be achieved by any other method (at least not as easily).

With such an impressive list of benefits already available, it might seem as though flex circuit technology has already reached its limits. However, the basic principle of continuous improvement is that it does not rest. Improvement demands that we persist in our efforts to find ways to make flex circuit materials and processes still better.

President John F. Kennedy made famous the words of George Bernard Shaw: "Some people see things that are and ask, 'Why?' I dream things that never were and say, 'Why not?'" It is evident from the order of his statement that Shaw appreciated the importance of first asking "Why?" For young children, "Why?" is a hallmark question as they try to comprehend the complex world about them.

But Shaw seems to have intuited that without that important and fundamental question, the equally important question "Why not?" has no place to start. "Why not?" sparks an inventive spirit. The innovator is often very familiar with the question "Why not?" and, in many cases, has made it a touchstone for their innovations by seeing the unseen before being manifested into reality.

Indeed, innovation is commonly a product of observation and "Why and why not?" questions. Such questions press the mind into action, which hopefully results in seeing (or dreaming of, as Shaw suggests) some missing piece or the boundaries of empty space that define the missing pieces. After these mind-opening questions, the other familiar questions of who, what, when, where, and how will be required to shape and mold a solution to the initiating question.

Indeed, innovation is commonly a product of observation and "Why and why not?" questions.

Thus, the first challenge that confronts the innovator is to see what is not there and to turn it from a vague, dreamy concept to physical reality. How does one approach such a challenge? Let's take a short "mind walk" to try to uncover and illuminate the missing pieces that await their moment of discovery. For this exercise, let's apply the idea to our venerable flex circuit technology and see what it might yield.

First, it is worth noting that once we become familiar with something—no matter what its nature—we become wedded to our perceptions of it. Technology is not immune. This is a trap that humans have been falling into for ages, though some have admonished us to avoid it. Shakespeare, for example, warned us in his play Antony and Cleopatra: "Make not your thoughts your prison." Unfortunately, it is something we are all prone to do.

Turning back to our technology—flexible circuits—it is clearly a highly enabling technology with many facets of materials, design, manufacturing, testing, etc. While the interdependence and interplay between these elements must be considered (changing one thing will typically impact another), it should not be an initial constraint. Instead, one should be unafraid and even encouraged to wander off the beaten path. There will be some blind alleys when not staying on the main streets, but these alleys can sometimes yield unexpected treasures that—while not of value to the current effort—could be useful in unrelated efforts later on.

Another thing to avoid early on is any consideration of cost. It is often the case that a process or device is expensive at the outset, but the price will come down with experience and more participants. Always be mindful of the potential to have your thoughts imprison your dreams and actions.

Those points aside, let's now quickly apply the "Why?" question to some aspects of flexible circuit technology to see what it yields. Spoiler alert: there will be no answers to follow, as those will be the reader's responsibility. Thus, the following questions are presented for readers to ponder on their own and hopefully come up with some "Why not?" ideas of their own. Consider the following: Why do we use only certain materials? Why do we need holes? Why do we use coverlayers? Why do we need lamination? Why do we need solder? Finally, for a little bit of controversy, why do we even need flexible circuits?

Remember, there are no right or wrong answers; they are merely questions that might help us all to break loose from our mental chains (escape our prisons, if you will) and think in new directions and dimensions.

Having opened this brief discussion and challenge with a quote from one of the world's greatest thinkers, it seemed appropriate to end with a quote from another great mind, Supreme Court Justice and philosopher Oliver Wendell Holmes, who astutely observed the following: "Man's mind, stretched to a new idea, never goes back to its original dimension." It seems doubly fitting knowing that the act of stretching also helps one to stay flexible in both mind and body. **FLEX007**

Joe Fjelstad is founder and CEO of Verdant Electronics and an international authority and innovator in the field of electronic interconnection and packaging technologies, with more than 150 patents issued or pending. To reach Fjelstad, click here.

The Myth About Rigid-Flex Costs

Flex Talk

by Tara Dunn, OMNI PCB with Anaya Vardya, AMERICAN STANDARD CIRCUITS

Do you cringe when you think of the option of rigid-flex? It is not an uncommon reaction when talking with designers and engineering managers about using rigid-flex to solve a packaging problem. Why? The most frequent answer is, "They are so expensive." While it is true that a rigid-flex PCB is typically more expensive on the surface when compared to rigid-board solutions with cables and connectors, a lot is being missed with that mindset.

Benefits

First, let's discuss the many technical benefits associated with rigid-flex solutions. Rigid-flex PCBs can:

1. Serve as a remedy to natural product packaging problems

Flexible circuits are often chosen because they help solve problems related to adding electronics inside the product they serve. They are a true three-dimensional solution that allows electronic components and functional and operation elements (i.e., switches, displays, connectors, etc.) to be placed in optimal locations within the product, assuring ease of use by the consumer. They can be folded and formed around edges to fit the space allowed without breaking the assembly into discrete pieces.

2. Reduce both weight and volume requirements

Flexible circuits are appreciably lighter than their rigid circuit counterparts. Depending on the components used and the exact structure of the assembly and final products, they can save as much as 60% of the weight and space for the end-product compared to a rigid-circuit solution. Additionally, their lower profile can help a designer create a lower profile product

than is possible with a nominal 1.5-mm rigid board.

3. Reduce assembly costs

Before the broad use of flexible circuits, assemblies were commonly a collection of different circuits and connections. This situation resulted in the purchasing, kitting, and assembly of many different parts. By using a flex-circuit design, the amount of part numbers required for making circuit-related interconnections is reduced to one.

4. Eliminate the potential for human error

Because flexible circuits are designed as an integrated circuit assembly with all interconnections controlled by the design artwork, the potential for human error in making interconnections is eliminated. This is especially true in the cases where discrete wires are used for interconnection.

5. Facilitate dynamic flexing

Nearly all flexible circuits are designed to be flexed or folded. In some unusual cases, even thin rigid circuits have been able to serve to a limited degree. However, in the case where dynamic flexing of a circuit is required to meet the objectives of the design, flexible circuits have proven best. Modern disc drives, for example, need the flexible circuit endure anywhere millions of flexural cycles over the life of the product. Other products, such as laptop hinge circuits, may only require thousands of cycles, but it is the dynamic actuation capability enabled by the flex circuit that is key to its operation.

6. Improve thermal management due to being well-suited for high-temperature applications

High temperatures are experienced both in assembly with lead-free solder and in the operation of higher power and frequency digital circuits. Polyimide materials are well-suited to the management of high-heat applications. Not only can they handle the heat, but their thinness also allows them to dissipate heat better than other thicker and less thermally conductive dielectrics.

7. Improve product aesthetics

While aesthetics may seem like a low-order advantage, people are commonly influenced by visual impressions and frequently make judgments based on those impressions. Flexible circuit materials and structures look impressive both to the seasoned engineer and the layperson. It can make a difference in the decisions made in some applications, especially those where the user gets exposure to the functional elements of the product.

The increasingly sophisticated electronics being developed are pushing more designs to rigid-flex. Thinking through the benefits listed above, you become convinced that rigid-flex is the right direction for your next project. The next step is convincing your boss or program manager that this concept is the best solution. You are now battling that same perception; rigid-flex is more expensive. However, you cannot compare only the cost of the rigid board and cables to the rigid-flex. You need to look more holistically at the total cost of the design.

Costs

Here are the key factors to consider when comparing the cost of rigid-flex to a PCB and cable solution:

1. Design

Because you are merging multiple boards, only one design is needed with a rigid-flex. With the rigid PCB and cable solution, multiple PCB and cable assembly designs are often required. The cost of generating each design should be included when doing a comparison of both options.

2. Cable and connectors

It is common for someone to compare the cost of the rigid boards with the cost of the rigid-flex and jump to the conclusion that the rigid-flex is too expensive. However, the cost of the cable and connectors should also be considered in this decision. This includes the cost of kitting for assembly, labor, in-process inspection, cable assembly test, final test, PCB tooling and test charges, and the cost of engineering time required for each of the items.

3. Assembly operation

Similar to the concept of the cost of the design, a rigid-flex solution requires only one assembly. The PCB and cable solution can require two, three, or even more individual boards to be assembled. The total cost of assembly should be included in this review. This includes a similar list to the one in point two, along with multiple set-ups of the assembly equipment, and engineering time required for each assembly operation.

4. Testing

Not only does rigid-flex require one test operation compared to possibly several for individual boards connected by cable, but it also provides the ability to test the full assembly before installation.

5. Order processing

The cost associated with processing orders is often overlooked. Rigid-flex is one unit. Multiple boards, cables, and connectors can require several purchase orders to be placed, monitored, received, inspected, handled, stored, and payment processed. These costs should also be captured in a comparison of both options.

Reliability

Without question, the rigid-flex option is considered a high-reliability alternative to the PCB and cable solution. For many years, rigid-flex was predominately a mil/aero solution, but over time has become common in nearly all markets. The connector is an integral part of the board; there are no solder connections between boards. With rigid-flex, the reliability is dependent on design, not on the assembly process.

It is easy to arrive at the conclusion that moving to a rigid-flex design does simplify things for designing, purchasing, assembling, inspecting, or even accounting. However, the question is, "Does this simplification justify the cost?" Each application should be reviewed individually. While not all-inclusive, Figure 1 shows a sample comparison and provides a good place to start a discussion.

Fabricators

Moving ahead with your rigid-flex design, how can your fabricator help?

1. Stiffeners versus rigid-flex

Flex with stiffeners to support component areas is a less expensive alternative to rigid-flex and worth the discussion. The primary difference in a simple design is the rigid-flex will

Item	Unit	Qty	Rate	Total
Cable assembly design	Hours	1	$ 40.00	$ 40.00
Rigid PCBs	Each	2	$ 10.00	$ 20.00
Connectors	Each	4	$ 5.00	$ 20.00
Wire/cable	Each	1	$ 5.00	$ 5.00
Wire markers	Each	1	$ 2.00	$ 2.00
Shrink tubing	Each	1	$ 3.00	$ 3.00
Cable ties/fasteners	Each	1	$ 2.00	$ 2.00
Assembly				
Kitting for assembly	Each	1	$ 5.00	$ 5.00
Labor	Each	1	$ 20.00	$ 20.00
In-process inspection	Each	1	$ 3.00	$ 3.00
Cable assembly test	Each	1	$ 3.00	$ 3.00
Final/test	Each	1	$ 3.00	$ 3.00
Misc. costs: Engrg. time, etc.	Hours	1	$ 40.00	$ 40.00
Order Processing				
PO generation	Orders	2	$ 85.00	$ 170.00
Receiving	Each	2	$ 15.00	$ 30.00
Incoming inspection	Each	2	$ 10.00	$ 20.00
Material handling/storage	Hours	1	$ 5.00	$ 5.00
Total Material Cost				**$ 391.00**

Figure 1: Key factors to consider when looking at the total cost of a PCB and cable solution.

have a plated through-hole connecting all the layers, while the FR-4 stiffener is used only for component support. The density of component areas is often the driving factor toward rigid-flex.

2. Stackup

Your fabricator can help ensure that you are meeting thickness and impedance requirements for the design. They will also provide guidance on materials that are in stock and materials that may need to be special ordered so that material lead-time can be factored into the project plan. Further, your fabricator can also discuss tradeoffs of various materials, so you can be sure you are designing with the most cost-effective construction.

3. Array design and panel utilization

Typically, panel utilization or the "number up" is the biggest cost driver for flexible circuit designs. As with rigid designs, fabricators price by production panel, with the piece price being the panel price divided by the number of parts per panel. It is important to understand your fabricator's preferred panel size. Common panels sizes are 12" x 18" and 18" x 24". Fabricators commonly use the outside one-inch border of the manufacturing panel for coupons and tooling holes. Effectively, when designing, optimizing the useable space of 16" x 22" and 10" x 16" with individual pieces or arrays will result in the lowest cost option.

Typically, panel utilization or the "number up" is the biggest cost driver for flexible circuit designs.

Rigid-flex often takes on unusual shapes that are not necessarily the standard square or rectangle we see with rigid boards. Standard panelization software may not consider this. If the design can be reverse-nested to increase the number of parts per panel, this can significantly impact price and is worth time for review when setting up the array configuration.

4. Dynamically flexing

Clearly communicating areas that your flex circuit will be dynamically flexing will greatly benefit your design. Your fabricator will be able to review the design to ensure you are following best practices. Further, when setting the tooling for manufacturing, they will be able to orient the circuits on the production panel properly. Copper grain structure now becomes critical. The orientation with the grain structure could impact the material utilization and piece price.

5. Blind and buried via structures

It is always recommended to interact with your fabricator when developing blind and buried via structures with flex and rigid-flex. As you develop these structures, you are adding base copper on various layers. This can impact the smallest lines and spaces possible on those layers.

A Case Study

The following is a case study that illustrates why it is important to work with your PCB fabricator during the design phase. We once encountered a telecommunication application that had a 50% failure during installation due to cracking of the copper in the flex area. When the customer came to us, we reviewed the stackup and redesigned it by:

- Converting stackup to adhesiveless materials
- Decreasing flex thickness from 11.8 mils to 8.4 mils (29% decrease)

The extra thickness was adding rigidity to the flex area and causing cracking.

Summary

There are many things to think about when considering a rigid-flex design to solve a pack-

aging problem. Flexible solutions provide numerous benefits, including space, weight, packaging, reliability, and more. Even with these benefits in mind, it can be difficult to justify the added expense when compared to the traditional approach of a rigid PCB and cable solution. It is easy to only make a comparison at a surface level. Digging deeper into the total cost also includes purchasing, receiving, inspection, and administrative cost. A higher number of purchase orders being generated for the PCB and cable solution when compared to a single rigid-flex design provides a more holistic view of total cost.

Moving forward with a rigid-flex design, it is highly recommended that you work closely with your fabricator for stackup, array design and material utilization, dynamic flex requirement, and advanced via structures to ensure that you are not unnecessarily introducing added cost. Your fabricator works with rigid-flex designs daily—take advantage of that knowledge! **FLEX007**

Tara Dunn is the president of Omni PCB, a manufacturer's rep firm specializing in the printed circuit board industry. To read past columns or contact Dunn, click here.

Anaya Vardya is president and CEO of American Standard Circuits. To read past columns or contact Vardya, click here.

Medication You Can Wear

Empa researchers are currently developing polymer fibers that can be equipped with drugs. The smart fibers recognize the need for therapy all by themselves and dose the active ingredients with precision and accuracy. Drug-releasing textiles could, for instance, be used to treat skin wounds.

For the "self-care materials" project, fibers are produced from biodegradable polymers using various processes. "The targeted use of the fiber determines which manufacturing process is best," explains Empa researcher and project coordinator René Rossi.

Delicate, light membranes with a large surface are formed during so-called electrospinning. If robust fibers are required (e.g., for protective clothing), it is better to draw the melted ingredients. In the end, all processes produce novel fibers, the nano-architecture of which is made up of several layers and components.

In the finished product, for example, antibiotics or painkillers are to be integrated into the fibers.Textiles or dressings that release a remedy under slight pressure or a stimulus of light can contribute to the quality of life of patients and at the same time relieve the burden on health care staff.

The system can also be used for preventive measures. The idea behind it: Where active substances can be released, substances are also able to penetrate the fiber in the opposite direction. In the case of premature babies, the sugar balance is particularly likely to be out of balance. With the help of such sensors, blood sugar can be monitored painlessly through the tender skin without the babies having to suffer from a prickly blood sample.

(Source: EMPA)

Excerpt: *The Printed Circuit Designer's Guide to... Flex and Rigid-Flex Fundamentals*

Feature by Dave Lackey and Anaya Vardya
AMERICAN STANDARD CIRCUITS

Designing Flex Circuits for First-Pass Success: Part 3

Editor's Note: This is the third in a series of excerpts from the book. The first two issues of Flex007 Magazine carried Part 1 and Part 2.

Other Specific Issues of General Concern

This series is not intended to cover all of the different issues related to flexible circuits, but instead provide a short list of key issues that often "fall through the cracks" based on our experience. The following examples are offered to help readers avoid certain traps that have ensnared flex circuit designers in the past.

1. High layer-count designs: There are a variety of challenges related to high layer-count flex designs (e.g., a 20-layer circuit with two rigid layers and 18 flex circuit layers). High layer-count designs are difficult for rigid circuit manufacturers and they are even more difficult for flexible circuit manufacturers, owing in part to the inherent dimensional instability of flexible base materials. Because of this, it is highly recommended that the designer engages early on with the fabricator to understand these issues and to work through any concerns with the supplier. Every design is unique, but experience can be a great teacher and the manufacturing engineer can be a great source of help in steering clear of the major pitfalls.

2. Bookbinder constructions: The term "bookbinder" comes from the days when book pages were bound in sections by sewing them down a center line. In the final construction, the center pages were more prominent and the outer pages withdrawn on the edges of the sections. Possibly it was noticed that all the pages could be made flush if they were cut to different widths before stitching, though it was generally much easier to cut the pages after stitching and folding. In flex circuits, the term

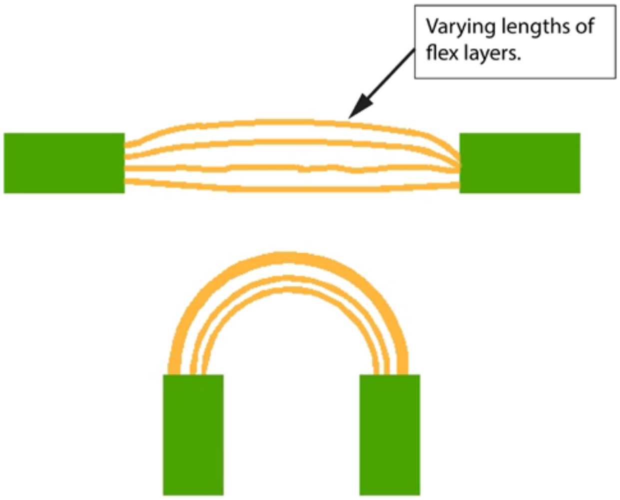


Figure 1: Bookbinder construction.

is applied to the staggering of the length of circuit layers through the bend within the design to provide greater ease of flexing in multilayer and rigid-flex designs. The technique is accomplished by adding slightly to the length of each succeeding flex layer, moving away from the bend radius. A common rule of thumb is to add length equal to roughly 1.5x the individual layer thickness, but the value can vary based on the tightness of the bend and the number of layers. Therefore, it is recommended that some modeling be carried out in advance of committing to manufacture.

A "paper doll" mock-up can be very instructive as a quick check. The extra length with each succeeding layer helps defeat whatever tensor strain might have otherwise built up in the outer metal layers of the multilayer flex, and it prevents buckling of the center of bend layers. If there are questions about the practice, the designer is advised to check with the vendor in the early stages for guidance and assure better first-pass yield. It is important to note that bookbinder requirements are extremely costly to manufacture. It requires a lot of additional up front tooling and fixturing costs (Figure 1).

3. Copper layers greater than 75 mm (2 oz. per square foot): Thicker copper foils are useful in many flex circuit applications where they can serve to address high-current/high-power requirements for both discrete traces and power and ground planes. They can also help hold the shape of a flex circuit which is formed to fit an application. The challenge of thicker copper is that it is more difficult to process the thicker copper and at the same time hold feature size accurately. This is because etching, which is the most common method of defining circuit features, is an isotropic process which works in all directions while at the same time undercutting etch resist and leaving traces narrower on top and wider on the bottom.

A potentially effective alternative is to begin processing with a thinner copper base and then pattern-plate additional copper in the areas where it is needed. That said, thick copper circuits are not necessarily to be avoided, but they should be approached with a full understanding of the issues. It is recommended that the designer consult with the fabricator about any issues and options before committing to thick copper.

4. Anchoring pads: When the flex layer is an outer layer in flex circuits and rigid-flex circuits, there is a weak point at the conductor/pad interface. Any stress to this area can cause a fracture of the conductor at this point. The best way to prevent this is to provide specific reinforcements to the isolated pads on flex layers. Anchoring the pads will assist with this type of design. There are a number of ways to potentially anchor pads and some of the popular ones are illustrated in Figure 2.

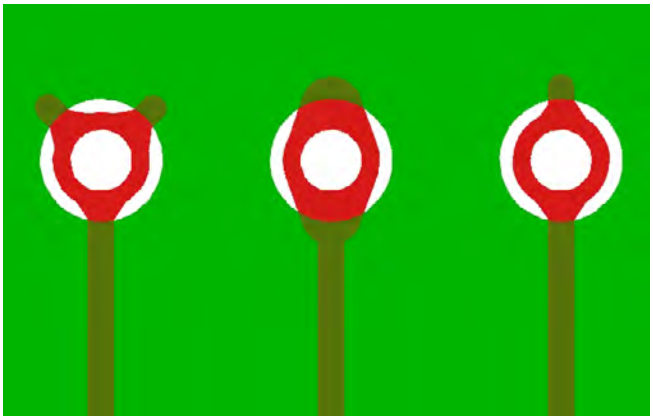


Figure 2: Anchoring pads.

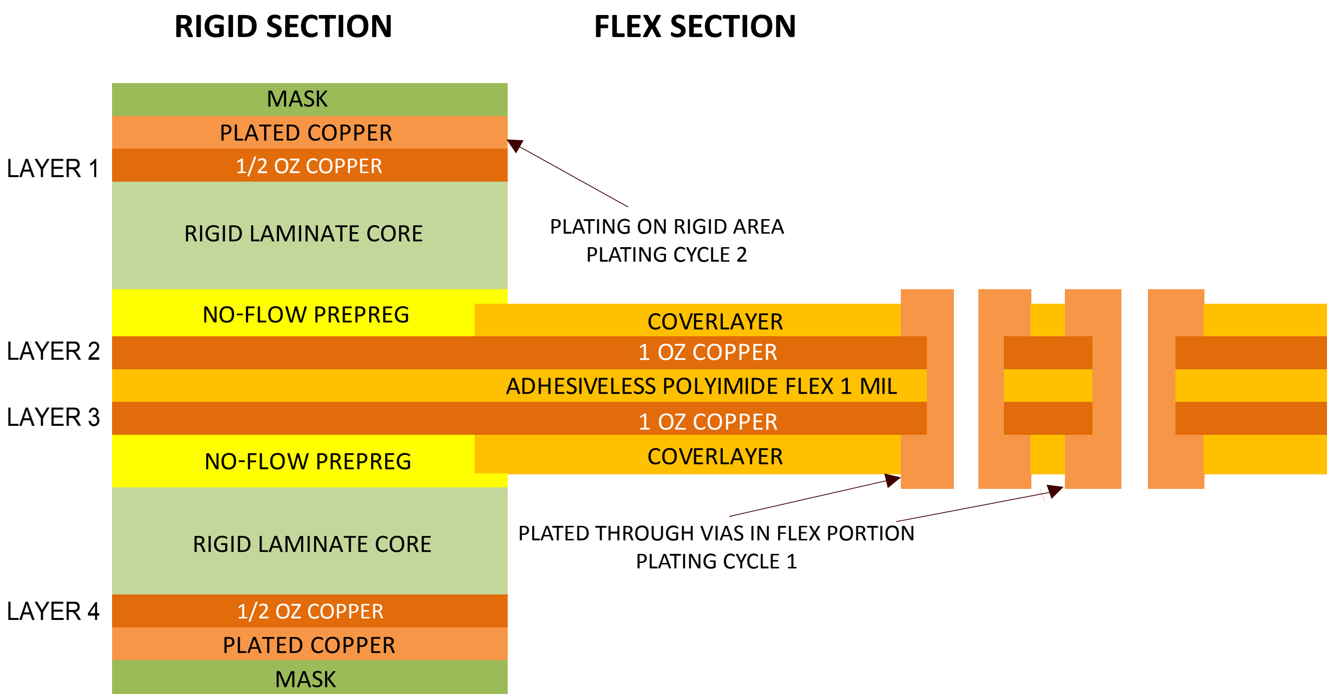


Figure 3: Rigid-flex with PTH in both the flex area and rigid area.

5. Creating holes located only in flexible sections of rigid-flex boards: In rigid-flex circuits, it is generally desirable to limit the drilling of through-holes to those areas where the rigid and flex areas are laminated together. However, owing to the diversity of design needs, there are occasions when holes are needed in the flexible areas. This requirement can have a significant impact on both the processing and the physical performance of the design. Figure 3 illustrates an example of this.

The processing aspect is related to the fact that at a minimum, a separate drilling step is required and if the hole requires plating, all process steps associated with plating must be carried out. The prospective impact on cost is readily apparent. It is well worth discussing the design with the fabricator's engineers before locking in such approaches to see if there might be a better solution. If not, at least the manufacturing engineer might be able to help suggest ways to make the circuit easier to manufacture and more reliable. With regards to reliability, any holes in the flexible sections should be kept out of the area which will experience the most flexing as these can cause stress risers and non-uniform performance.

6. Rigid-flex circuits with more than ten layers or three flexible cores: It can hopefully be appreciated by the reader that the greater the number of layers in a rigid-flex circuit, the greater the opportunity for errors, especially the compounding of small errors which are insignificant in and of themselves, but which grow with the increase in handling and processing. It is not possible to make blanket design recommendations on this topic, because the potential variety of designs is virtually infinite. Thus, it is highly recommended that the designer check with the fabricator's manufacturing engineers to get their thoughts on what issues might come up and what problem preemptive design choices might be made.

7. Flex section as an outer layer: One of the simplest forms of rigid-flex are those with flexible sections on the outer surfaces rather than on the inside. It is possible to make a two-layer rigid-flex circuit with a flex circuit on one side and none on the other, with the two sides interconnected by plated through-holes. To assure that the flex areas remain flexible after processing, there are special processing requirements, such as making sure that the rigid and flexible

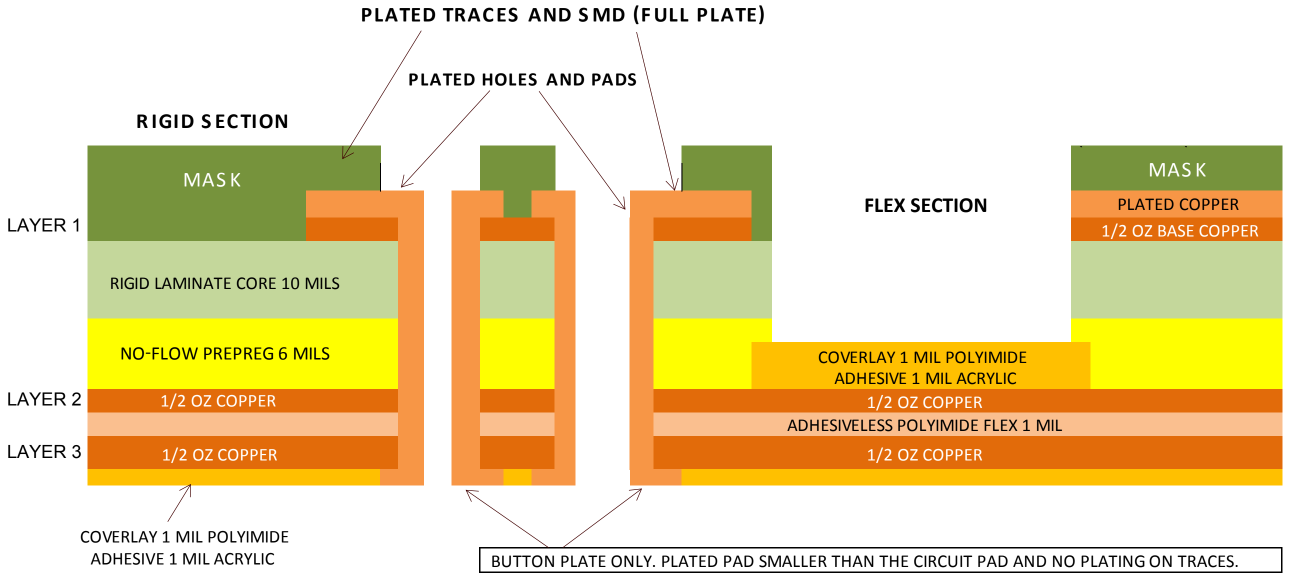


Figure 4: For extreme flexing, consider plating only the holes and pads on the flex circuit side.

sections are not inadvertently bonded together. Additionally, when utilizing a flex core as an outer layer in a multilayer construction it is important to note that all copper features are typically plated on the outer layers. If it is your intention to flex this device to any extreme or more than once it would be advisable to have only the holes and pads plated on the flex circuit side (Figure 4).

Electrodeposited copper is brittle and plating the traces on the flex side may crack when flexed. These structures are relatively straightforward in terms of processing but it is once again worthwhile to check with the fabricator's engineers for review and comment before submitting the design for quote.

8. Flexible circuit structure with multiple discrete breakout sections: One of the most attractive features of flexible circuits is their ability to serve as miniature wiring harnesses. Flex circuits can interconnect—in three-dimensional space—the various elements (e.g., modules, switches, and power sources) of an electronic product. In many cases, such as with one and two metal layer circuits, this is a primary objective that can be easily accomplished by simply designing the circuit with discrete routes to desired terminations in panel form and then routing, punching or cutting the circuit from the panel. In the case of multilayer and rigid-flex circuits, this activity is not so simple and much more attention to design and process detail is required. Because of the infinite variety of design possibilities, it is not possible to give a generic recommendation beyond consulting with the fabricator's manufacturing engineer to pre-determine a best approach (Figure 5).

9. Flex layers with multiple layer separations and discrete routes: As with the previous discussion, it is possible to prefabricate internal layers with the same multiple discrete routes and, moreover, to route them from sepa-

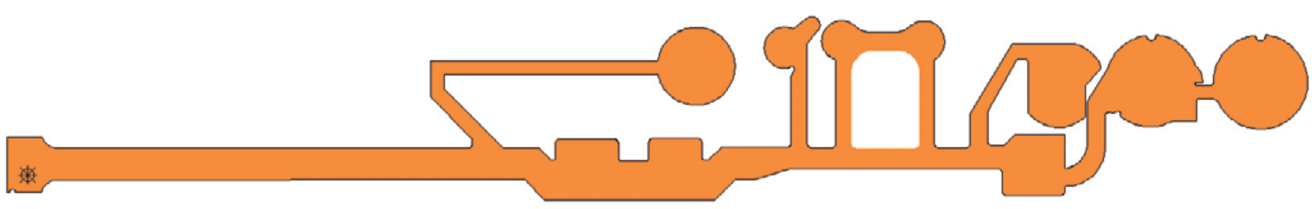


Figure 5: Flex with multiple discrete breakout section.

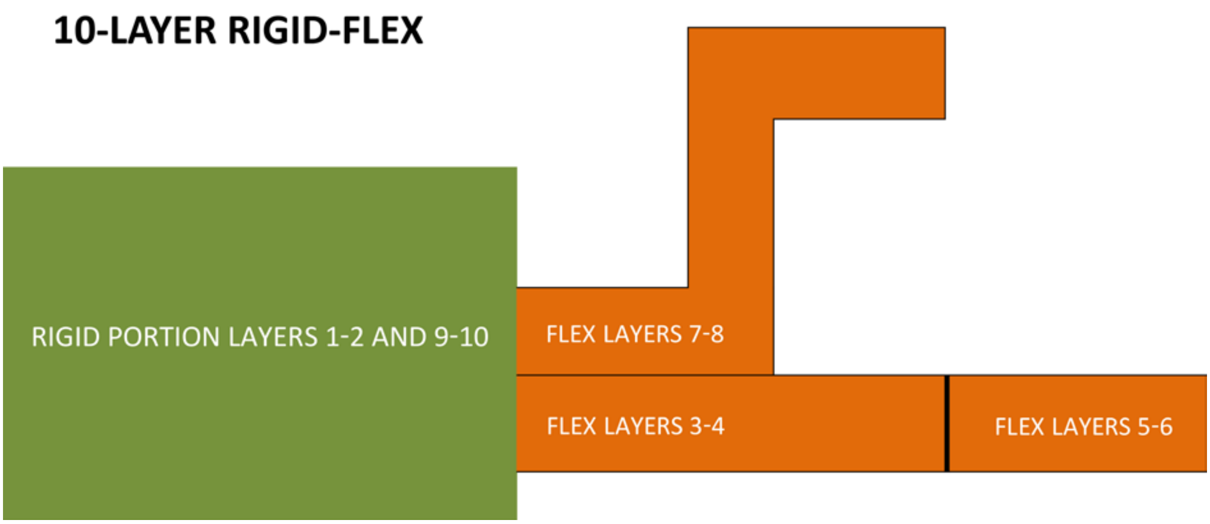


Figure 6: 10-layer rigid-flex with multiple layer separation and discrete routes.

rate flexible layers of the design. It is a fundamental compounding of the challenge described earlier and as such it requires even more attention to detail and even more consultations with engineering staff because the process planning can be quite complex. See Figure 6.

We hope you have found our three-part series "Designing Flex Circuits for First-Pass Success" both enjoyable and educational; it was intended to help flex PCB designers consider the many issues that can impact the PCB fabricator and product reliability. Look for more flex PCB articles from us in the upcoming issues of *Flex007 Magazine*. **FLEX007**

Visit I-007eBooks to download your copy of American Standard Circuits' micro eBooks today:

- *The Printed Circuit Designer's Guide to... Flex and Rigid-Flex Fundamentals*
- *The Printed Circuit Designer's Guide to... Fundamentals of RF/Microwave PCBs*

Dave Lackey is vice president of business development at American Standard Circuits.

Anaya Vardya is CEO of American Standard Circuits.

Part-Organic Invention Can Be Used in Bendable Mobile Phones

Engineers at ANU have invented a semiconductor with organic and inorganic materials that can convert electricity into light very efficiently, and it is thin and flexible enough to help make devices such as mobile phones bendable. It also opens the door to a new generation of high-performance electronic devices made with organic materials that will be biodegradable or that can be easily recycled.

The organic component has the thickness of just one atom—made from carbon and hydrogen—and forms part of the semiconductor that the ANU team developed. The inorganic component has the thickness of two atoms. The hybrid structure can convert electricity into light for displays on mobile phones, televisions and other electronic devices.

"We have the potential with this semiconductor to make mobile phones as powerful as today's supercomputers," said Mr Sharma from the ANU Research School of Engineering.

(Source: Australian National University)

Flex007 News Highlights

Cirexx Supplies Rigid-Flex Circuits for Innovative Medical Application ▶

Cirexx International has worked closely for several years with engineers at a major medical products manufacturer in the Midwest, to develop state-of-the-art rigid-flex circuit boards for use in cognition detection systems. They are multilayered, rigid-flex construction with Black Kapton over the flexible sections.

PCB Designers: Perfect Your Data Package with New eBook from Prototron ▶

For PCB designers, producing a comprehensive data package is crucial. Learn how to perfect your data package with I-Connect007's most recent title: The Printed Circuit Designer's Guide to… Producing the Perfect Data Package.

Binghamton Designated as Nextflex New York Node for Flexible Hybrid Electronics Initiative ▶

NextFlex has designated Binghamton University to be the New York "Node" for its flexible hybrid electronics (FHE) initiative. Binghamton will design, develop and manufacture tools; process materials and products for flexible hybrid electronics; and attract, train and employ an advanced manufacturing workforce.

I-Connent007 Publishes Automation eBook by Happy Holden ▶

The latest title in our eBook library is Automation and Advanced Procedures in PCB Fabrication. This book provides an in-depth look at automation, computer-integrated and computer-aided manufacturing, mechanization, and chemical monitoring and control.

FPCB Market to Display Significant Growth by 2027 ▶

The demand for flexible PCBs by manufacturers of smartphones, other mobile devices, LCD display, connectivity antennas, and rechargeable batteries, is currently on the rise. Exploding consumer electronics sector, soaring popularity of IoT, and growing applications in the automotive sector are identified as having a positive impact on the sales of FPCBs in near future.

ESI's CapStone FPCB System Delivers Highest VIA Drilling Throughput in Industry ▶

Electro Scientific Industries, Inc. announced the availability of its new CapStone flexible printed circuit board laser processing system, which offers 2X throughput improvement over its predecessor for processing blind and through hole vias, the highest in the industry.

Insulectro Hires Michael King as DuPont Product Manager ▶

Insulectro, the largest distributor of materials for use in printed circuits boards (PCB) and printed electronics manufacturing, has hired Michael King as product manager its DuPont product offerings.

Atotech Launches Next Revolution in Electroless Copper for Advanced FPCB ▶

Atotech has introduced a new horizontal electroless copper process specifically developed to ensure a blister-free electroless copper deposition and shiny surface appearance after electrolytic copper plating. The new process is compatible with electro-deposited (ED), rolled and annealed (RA) as well as "super-flexible RA" (HA) copper foils.

Pointers for Your First Rigid-Flex Design

Flex Time

by Bob Burns, PRINTED CIRCUITS

If you are new to rigid-flex designs—or have never done a rigid-flex PWB layout—you might wonder how it is similar to and different from hardboard design. In previous columns, I've discussed cost drivers in rigid-flex boards and applications where rigid-flex designs will outperform all other packaging methods, which more than justifies the increased cost. In this column, I'll address critical items you need to know to successfully create a stable and robust rigid-flex design.

Layers

Gerber files, artwork, and other aspects of communicating your rigid-flex design to a fabricator are very similar to what you would provide your fabricator for a hard board. Some folks don't realize that the flex layers extend all the way through the rigid section on a rigid-flex board. This is why rigid-flex boards provide such a high degree of reliability in high-shock, or high-vibration, environments. The flex layers are integrated right into the board, just like a layer of 0.004" core in a rigid board.

A typical fabrication package will look similar to a hardboard design. The Gerber files, drill files, and design guidelines and recommendations will be very much alike. Where they differ is in controlled impedance requirements, material layups, detailed fabrication drawings, and special design rules around the rigid-to-flex transition areas. Thus, a typical rigid-flex fabrication package will look comparable to a hardboard design package.

Impedance Considerations

Controlled impedance traces have become more prolific in digital and high-speed circuit designs. The software and test vehicles to provide this level of control have progressed in step with the demand as well. The dielectric materials in the flexible sections are different than hardboards and generally provide better electrical performance. The coverlayers and bondplys also offer better electrical performance.

These materials have varying dielectric constant (Dk) values and should be modeled in soft-

ware that is designed to predict how each of the dielectrics, reference planes, and circuits relate to one another. Trying to do this in a rigid-flex design using free online impedance calculators will almost always return false values. There are just too many interactions to use single-value calculators. Additionally, some of the material suppliers give global DK values when they can be different at different signal speeds in reality.

The best path forward is to purchase the software, which is available as a standalone product for an annual license fee and is often included and built into some of the more popular CAD PWB layout tools. The software is not cheap, but it is far more accurate than the free online tools.

Whether you decide to purchase the software or not, it is always wise to involve your fabricator at the start of your design to either predict the impedances you desire, or to double check your work if you used your own software. Your fabricator does impedance modeling dozens of times a day and has modeled impedance circuits for many years. They will have a material library with Dk values for the different material constructions and will know all of the impedance values for every thickness of every dielectric they use. For each impedance value that you want to be modeled, tell your fabricator the value you desire, the type or characteristic of differential, on what layer(s), what speed the signal is at, what layer(s) the reference plane(s) are on, and any mechanical considerations (e.g., the board cannot be thicker than 0.062", etc.).

There are two important differences to keep in mind with impedance modeling of rigid-flex circuit boards. The first is that the values, trace widths, and spacings will be different in the flex sections than in the rigid sections. Your fabricator should provide you with a model showing both calculations whenever you have impedance-controlled circuits in both the flexible sections and the rigid sections of the board. As a designer, this will require you to neck down the circuits to their correct geometries and spacing. The neckdown should occur 0.050" or more into the rigid board to prevent stress on the circuits at the neckdown area and the flex-to-rigid transition area.

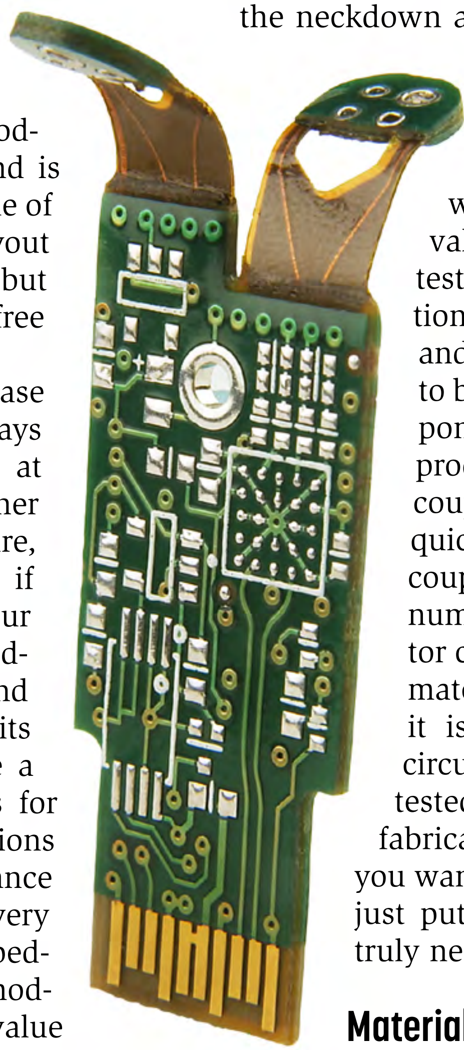


Figure 1: Six-layer rigid-flex board with controlled impedance circuitry.

You should also note that the number of impedance values can quickly multiply with rigid-flex designs. Each value often needs modeling and testing in the flex and rigid sections of the board. Because of this and the fact that each value needs to be tested in the impedance coupons that are built into your part's production panels, the size of the coupons can grow very large, very quickly. The larger the impedance coupons on the panel, the fewer number of parts that your fabricator can fit on the panel, which ultimately increases your cost. Thus, it is wise to specify only those circuits that you truly need to be tested on your print. You and your fabricator can model all the values you want through the whole PWB, but just put on the print the values you truly need.

Material Layup

If you modeled the impedances as previously described, you are approximately 90% of the way towards a material layup. The report will give you the material cross-section with copper thicknesses, dielectric thicknesses, Dk values, etc. If you don't have any impedance values to model, or you just need a straightforward material layup, ask your fabricator for their recommendations. Here is what they will want from you to get started:

- The overall number of layers in the rigid section(s): rigid sections can have differing amounts of layers of circuitry, but they should all end up the same thickness
- Desired copper thicknesses in the rigid section(s): innerlayers and outer layers with plating
- Number of layers in the flexible section(s)
- Desired copper thickness in flexible section(s)
- If there are more than three layers in the flex section, do you want them bonded together or loose-leaf?
- The desired overall thickness of the rigid board(s): over laminate, plating, or solder mask?
- Materials desired (FR-4, polyimide, etc.)
- Final finish
- Special requirements (UL, RoHS, REACH, lead-free and halogen-free assembly, etc.)

With this, your fabricator should be able to provide you with a suitable material layup as a starting point, which you can refine from there. Also, remember that many of the most popular laminates available on the market do not have a corresponding no-flow prepreg. Rigid-flex manufacturers have to use no-flow prepreg to keep the uncured resin from flowing onto the flexible areas of the board during lamination. Your fabricator can recommend laminates with corresponding no-flow prepregs that will meet your requirements.

Another good starting point for material layups is our Valu Build brochure[1]. Valu Builds offer simple, stable, and robust material layups for rigid-flex that are also very economical. They are ideal for someone who is just starting rigid-flex, looking for a good entry point, and seeking the lowest cost in a rigid-flex design.

Detailed Print

Board designers and their fabricators often see the print as a list of requirements, which it surely is. But much more than that, the print communicates to the fabricator what your desires are as the designer. Without that communication, the fabricator isn't always sure what you want. This is especially true for rigid-flex designs. Gerber files show your data and what you desire for holes, etc., but often it is not possible to tell where the rigid-to-flex transition areas are in the Gerber layers. This is where a detailed print—often much more so than an equivalent hardboard design—shows your fabricator precisely what you want.

Any dimensions across the flexible portions of the board should be referenced dimensions only. The flexible areas will expand and contract with temperature and humidity changes, so dimensions across the flexible portions of the board should be for reference only.

Rigid-to-Flex Transition Area

Design rules change around the flex-to-rigid transition area. There is a keep-out area on both sides of the rigid-to-flex transition line, particularly on the rigid side of that line. The keep-out area varies by the fabricator, but most fabricators will want you to keep all pads, traces, and vias a certain distance away from that line. In our case, we want all traces and the edge of pads at least 0.025" from the line and the edge of all drilled holes more than 0.050" from that line.

The reason is due mostly to cut-back coverlayer manufacturing (sometimes referred to as bikini processing). In high-reliability rigid-flex design and manufacturing, the coverlayer and bondply do not extend all the way through the rigid part of the board. They will typically extend 0.025" to 0.100" into the hard boards, but that also varies by the fabricator. The reason for using cut-back coverlayer is that the acrylic adhesive used to bond the coverlayer has a relatively high Z-axis coefficient of thermal expansion (CTE) rate—much higher than the surrounding laminates. During thermal cycling—think of RoHS and lead-free assembly temperatures—the expansion can put too much pressure on the vias and cause them to crack. Also, the acrylic adhesive does not drill, prep for plating, or plate well. Overall, it is not desirable in the rigid sections of your board.

There are times when it is not possible to use the cut-back coverlayer technique, and you must use full-sheet coverlayer/bondply.

However, whenever possible, use cut-back coverlayers and bondplys to provide the highest package reliability possible. Because of cut-back coverlayer, the edge at the flex-to-rigid transition area can have a slight radius to it. Any circuits or plated features in this area will struggle to image faithfully and will suffer yield loss.

Any circuits or plated features in this area will struggle to image faithfully and will suffer yield loss.

For the same reason, the edge of the drilled via needs to be kept back from that transition line. If the vias are drilled partially through coverlayer and bondply and partially through prepreg, they will not yield—which typically shows as plating defects and opens at electrical test. It is the edge of the drilled hole that is critical and not the finished via size. If you call out a 0.012" finished hole on your design, fabricators usually drill that at 0.006" larger than the finished via size to accommodate plating thicknesses. If you put the edge of the finished via on the edge of the keep-out area, the drill itself will be drilling within the keep-out area.

It is wise to involve and consult your fabricator as to what their keep-out limitations are in the rigid-to-flex transition areas of the board, which can often vary by design. These are not absolute rules, just recommendations to get the best design with the highest yields and lowest overall cost possible. FLEX007

References

1. Printed Circuits' Valu Build Brochure.

Bob Burns is national sales and marketing manager for Printed Circuits Inc. To read past columns or contact Burns, click here.

FLEX SURVEY: DESIGN PROBLEMS

What are your biggest problems related to flex design?

In a recent survey, the I-Connect007 research team asked readers who work with flexible circuits to list their biggest problems related to flex design. Here are a few of the replies, edited slightly for clarity:

Alex Forbes, *Rakon:*
Understanding how to design a flex PCB that is easily manufacturable and robust.

Dennis L. Buster, *Seagate Technology:*
Impedance control.

Gil Leal, *Emerson Process Management:*
Lead time and cost.

Hilbrand Molema, *Variass Electronics:*
No real issues. We have gained a lot of knowledge over the years.

Meet All Flex's New President and CEO Matt Keithly

Matt Keithly reviewing All Flex's production process at their facility in Northfield, Minnesota.

Feature interview by the I-Connect007 Editorial Team

All Flex Flexible Circuits and Heaters recently appointed Matt Keithly as their new president and CEO. In this exclusive interview, Keithly discusses his background, the direction of the company, and topics related to flexible circuits and other areas of All Flex's business.

Patty Goldman: Matt, congratulations on your new position with All Flex. Can you tell our readers a little more about yourself?

Matt Keithly: I spent 25 years with Emerson Electric. I started in marketing and moved into sales and sales management roles with a few different business units, but primarily in the HVAC (heating, ventilation, and air conditioning) industry, as well as the major appliance or white goods market. My responsibilities were primarily focused in the original equipment manufacturer (OEM) channel by offering gas and electrical controls that were integrated into the customers' products.

In late 2011, I had the opportunity with Emerson to move to Minneapolis, Minnesota, from St. Louis, Missouri, to work for a more global business as opposed to one that was predominately North American; the business name of Emerson's was Control Techniques. They are an automation company that specializes in variable speed drives and servo motors for industrial automation applications. Minneapolis is the American headquarters for Control Techniques while the global headquarters is in the UK.

My role was VP of Americas for Control Techniques across all functional areas, but I focused on sales and marketing, prospecting and finding new customers, and business development. The business was managed out of Minneapolis and one of our facilities in Cleveland, Ohio, to support customers in the Americas with the distribution of products and what we call "late cycle manufacturing" to configure and customize products for our customers' applications.

Goldman: What attracted you to All Flex?

Keithly: What mainly attracted me to All Flex was wanting to pursue something different. First, I like the culture of Granite Equity Partners, All Flex's parent company. They are Minnesota based and seek companies that fit their business model. Granite Equity Partners is unique because they are committed to the community where each business is located,

and want to preserve the companies in that space. All Flex in Northfield, Minnesota, fit their business model; they want to try to maintain employment and help the businesses prosper in communities where previous owners and management started them.

This was a unique value proposition for me. It's very exciting and I was very attracted to it. They also support the businesses for growth. Another thing that attracted me to All Flex is it's a business that has been performing well and is in some similar spaces to where I've been in the past. I haven't been in the flex circuit space, but in both my automation background at Emerson and electronic controls in HVAC, there are some similarities in electronics and controls technology and manufacturing. Overall, I was attracted to their specialties and culture. I like the fact that it's a customer-focused organization in all parts of the business, not just the sales and marketing team.

Goldman: What other businesses are associated with Granite Equity Partners?

Keithly: They're fairly diverse. There is Altimate Medical, which designs and manufactures a full line of adult and pediatric sit-to-stand devices, which are used to serve patients with indications such as spinal cord injuries, paralysis, multiple sclerosis and cerebral palsy. There's also a company by the name of DeZURIK, which is a global leader in valve technologies for water and wastewater treatment, as well as other industrial applications. There's GeoComm, the leading provider of geographic information and communication systems to emergency 911 call centers across the US. GEOTEK is a designer, manufacturer and distributor of reinforced fiberglass pultrusion products for the electric utility and animal containment markets. Further, there is Massman Automation, a leader in the design and manufacturing of precision automation machinery. Microbiologics offers the largest and most diverse line of ready-to-use quality control microorganisms, which are sourced from the world's leading culture collections, packaged and delivered around the world. Finally, Vector manufactures and distributes market leading vinyl windows and patio doors throughout the upper Midwest.

Goldman: Where do you see All Flex going in the next few years?

Keithly: I'm not here to disrupt the strategy as the business is performing well. We're in the flex industry space and starting to get exposure to more rigid-flex applications. This is a relatively new space for us and we are looking to accelerate growth. We will evaluate where to invest internally in technology and engineering capabilities, or do we seek acquisitions that make fit and bring in additional technology and capabilities to allow us to grow faster and serve customers?

Right now, I want to continue what we're doing and perhaps look at accelerating those efforts. We've been on a good trajectory. The business and leadership team has been investing capital into the company to support the growth and keep up with demands to support our customers' technology base, and we're certainly going to continue that. We've made a number of large investments in 2018 with some more to go in the next three months, we have additional capital initiatives to support our customer base that will deploy in 2019.

Barry Matties: When you look at growth, do you expect growth in the flex market?

Keithly: The industry numbers indicate the market is up about 9% in 2018. I don't know if we can count on a similar trend in 2019, it's still early. For our business, we will continue to focus on supporting our customers and seeking new opportunities. We have a diverse North American customer base and a wide variety of applications that fit our capabilities.

Matties: You mentioned different regions. It will be interesting to see what happens with the tariffs and all the other impacts going on in North America. How do you view the North American market versus the rest of the world?

All Flex Flexible Circuits and Heaters headquarters located in Northfield, Minnesota.

Keithly: Our business is predominantly North American based. We don't have a significant international presence, so I think it's too soon to say. We reviewed the recent release of the tariffs. I suspect it won't impact us in the interim from a growth perspective due to the timeframe to convert new opportunities. While quoting and manufacturing lead-time's at All Flex is relatively short—All Flex prides itself on the fastest turnaround for our customers—the design and approval process of the customer base for new products can be lengthy. If they're single sourced today or have a couple of sources and the tariffs are impacting their pricing, that may accelerate their interest in approaching companies like All Flex, but the time to go through the qualification period may be a bit extended, so I don't know that we'll see a significant impact in 2019. I'd love for there to be a positive impact, but I think it's too early to say. Thus, we're not counting on the tariff implications—whatever those may be—to help us in our business. We're more focused on things we can control and the types of customers and industries that we're pursuing.

Matties: *Flex007 Magazine* is geared primarily towards the buyers and designers of flex, users, and OEMs. What sort of relationship do you have with the OEMs and are you in that deep in the supply chain process?

Keithly: Yes, we are. As a company, we predominately focus on OEMs. If you look at our top customers, we classify them as Tier 1 and 2. We have direct relationships with the customers as well. Our approach is to market ourselves, so they know our capabilities, rapid response, customer focus. We also want to reach existing customers to capture a higher percentage of their business through new applications and increase awareness with prospective customers who perhaps don't know our capabilities. We have put a considerable amount of effort into spreading the word so people can find us, in addition we're proactively marketing ourselves to the industry.

Matties: When you're dealing with an OEM, what sort of challenges do they face in this arena utilizing flex?

Keithly: From a technical perspective, I don't know that I can give you a good answer. What I've learned in these few weeks is the speed to market, required technology to use flex versus more rigid PCB designs, and the capability to offer our expertise to ensure it's appropriately designed for use in the application. Speed to market is always a challenge and we pride ourselves on the rapid response for our customers.

Matties: You mentioned you're investing in equipment. What sort of investments are you making in the capability of your offering?

Keithly: We've invested around our automated optical inspection, drilling and laser operations so we can continue to market ourselves with shorter lead times and quick response for our customers. In addition, we've invested in equipment to support our Maxi-Flex extended length flexible circuit capabilities.

Matties: What sort of lead times are people expecting these days?

Keithly: It depends on the product and application, but we pride ourselves on a rapid response of getting a specification or helping the customer in the design process, turning in a quote in 24-48 hours and then manufacturing capability within two to three weeks. This can't be done on every possible design or configuration, but it's a rule of thumb that we strive to achieve.

Matties: At All Flex, are you doing bare board fabrication alone or do you offer assembly as well?

Keithly: We also have a value-added business where we'll take the flex circuit and include assembly capability with our surface-mount lines to add components, connectors, leads, and various assembly capability within our business. We continue to see that capability grow in importance as more customers have an interest in letting their supply base do that work for them. For our business—as far as what amount has additional value beyond the actual flex circuits—a high percentage requires additional assembly work for our customers.

Matties: There are a lot of shortages going on in the supply chain. You've only been at All Flex for a few weeks, but how is the supply chain being managed and are you feeling an impact with component shortages?

Keithly: I've heard of shortages in the industry, but we have not had significant disruptions impacting our business. We continue to work with our suppliers closely and make sure we understand the supply chain trends. With my background in electronics, I've seen lead times well beyond a year on components, so we try to stay close with our customers on their requirements and what they're expecting. We're going through the planning process for 2019 right now by attempting to provide that visibility to our supply base.

Matt Keithly, new president and CEO at All Flex.

Matties: You're coming in as the new president and CEO, so you must be either setting a new culture here or carrying on a culture. Could you talk more about the culture that you're bringing as a leader of the company?

Keithly: Most of my career has focused on the customer side of the business including marketing and sales, and more recently, more of the general management side with the other functional areas of the organization. The culture here is very customer focused, and regardless of who you're talking to in the organization and which department you're in, there's an interest in understanding what the customer's expectations are and collaborating across the various departments to work together to meet those customer requirements.

Fortunately for me, we have a strong culture already in place. As we continue to grow, I think the question will be, "How do we maintain that culture to make sure we can continue to support the customers—with a differentiator on our responsiveness and attention to lead time—to make sure we have the capacity and resources in place to maintain that value proposition?" As of today, it's a matter of what additional investments do we need to make and how do we continue to grow and plan our growth to keep the culture in place.

Matties: Every leader comes in with their own style. What sort of management style are you bringing to this company?

Keithly: My style is open, accessible, and focused on customers. I've already spent time across the organization in communication meetings to cover all the shifts and meet with small work-

groups to introduce myself and the organization as well. I want to hear and listen, and then determine how I can help continue the growth and maintain the tremendous customer-focused culture here. It aligns with my background and what I've done in the past at Emerson.

Matties: Emerson certainly has a rich history. Coming into All Flex, which has had a great reputation for many years, I think you made a good choice in joining this team. We've been doing business with All Flex for many years, and your team has always presented a lot of content as leading technical experts in the field. How are you going to carry that forward in the future?

Keithly: We need to make sure we have the right presence, and that can be something as simple as our website. We've upgraded our heater product website, and we're working on improving our core All Flex website for the rest of our business to make it more user-friendly

We need to make sure we have the right presence, and that can be something as simple as our website.

and easier to navigate. We've also done a fair amount of work on social media piece too. I'd like to see us figure out how to do more of that. We need to market ourselves to new, emerging engineering organizations and talent and make sure we're keeping up with their expectations. We haven't talked much about the print side of things—not because it isn't important—but because it hasn't surfaced yet in our discussions. We've put forth quite a bit of effort to seek out and support the right types of trade shows that fit the type of customers that we've done business with and/or customers we're trying to market ourselves to, so that's another key area for us to continue pursuing.

Matties: When you look at markets, what do you look for as leading market indicators and what grabs your attention?

Keithly: The economic piece of it is always helpful to understand what's going on with the economics in our markets. The markets we're in—medical and defense and aerospace are core markets for our business—have been performing well, but we're always looking for opportunities to diversify and industrialize. Fortunately, we're in many different markets, so if there is a weakness in some, we have enough in our pipeline to capture business so we can continue the growth we've been having.

Matties: In your first few weeks at All Flex, what has been the greatest challenge for you so far?

Keithly: The greatest challenge is trying to make sure I gain an understanding of what's going on in the various functional departments of the business. I want to meet everyone in the organization and listen as much as I can to capture information from the many people who have a lot of expertise in the flex industry specifically within All Flex. I don't know that it's a big challenge, but that's what I'm focusing my time on now and trying to be effective.

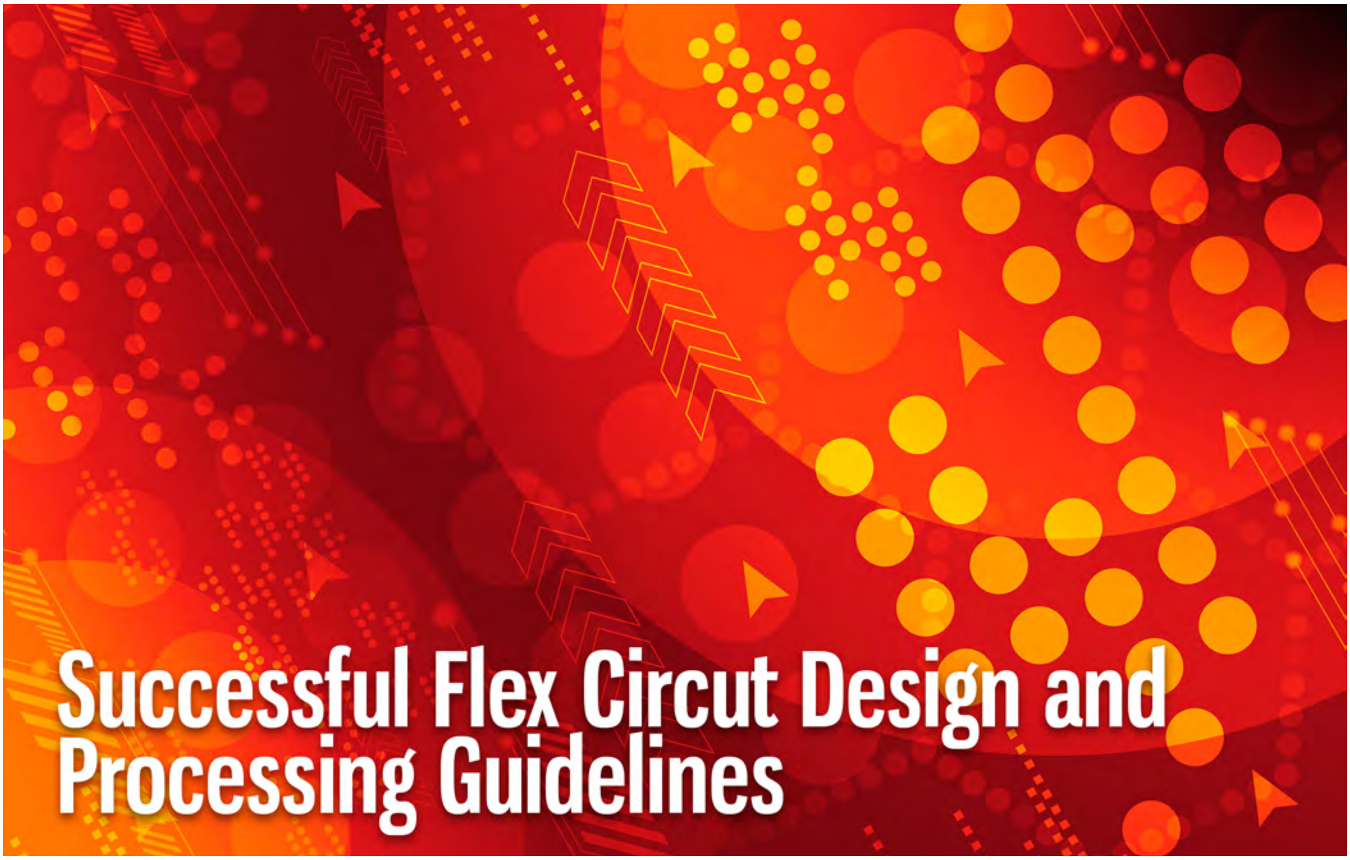
Matties: That makes a lot of sense. It will be fun to catch up with you to see how things progress in the next six months or so.

Keithly: I appreciate the opportunity to talk with you today as well.

Matties: Yes, it has been a pleasure meeting you. Good luck in your new career with All Flex. If there's anything we can do to help you, please reach out.

Keithly: Most definitely.

Goldman: Thanks so much for your time. **FLEX007**



Successful Flex Circut Design and Processing Guidelines

Feature by Tuan Tran
GREEN CIRCUITS

With the use of sensors and technology in everything from mobile phones to refrigerators, automobiles, and wearable medical devices, circuit boards are a component in many different types of products. In today's world of electronics, any product with an on-off switch contains a circuit board.

Due to their versatility, the use of flex circuits is one of the fastest growing product market segments. With the introduction of flex and rigid-flex circuits, engineers have been given the opportunity to be more creative in designing new and innovative products. Flex and rigid-flex boards are built to fit into tight, three-dimensional spaces while ensuring resistance to mechanical wear and vibration. Engineers can design products that require boards to fit into tight spaces, twist and turn for packaging, and make the product live in a more dynamic environment. These flexible circuits have the same performance levels as traditional rigid FR-4 boards; however, they have their own nuances and considerations when it comes to design, fabrication, and assembly.

Design and Layout

When designing a flex circuit, it is important to know the specific application for the circuit. Will it be used in a static or dynamic environment? If the board will reside in a static environment with little to no movement, the circuit design needs to have the appropriate amount of flexibility so that it can be easily installed within the product. Alternatively, if the board will exist in a dynamic environment where the board will continuously flex back and forth, a level of flexibility that can withstand continuous movement needs to be considered in the design.

Will the application require a flex or a rigid-flex circuit? If the product requires one-sided surface-mount technology, then a fully flexible board may be the best option. If the product requires two-sided SMT, then a rigid-flex board is needed.

At first, there may be some apprehension to laying out a flex circuit board because it is

often assumed that it is different than a rigid board. The fact is that laying out a flex circuit board is like a rigid board with just a few differences. The setup of the software layers and the output files are the same as a rigid board; however, differences exist in the cover and stiffener layers with some basic design rules to keep in mind.

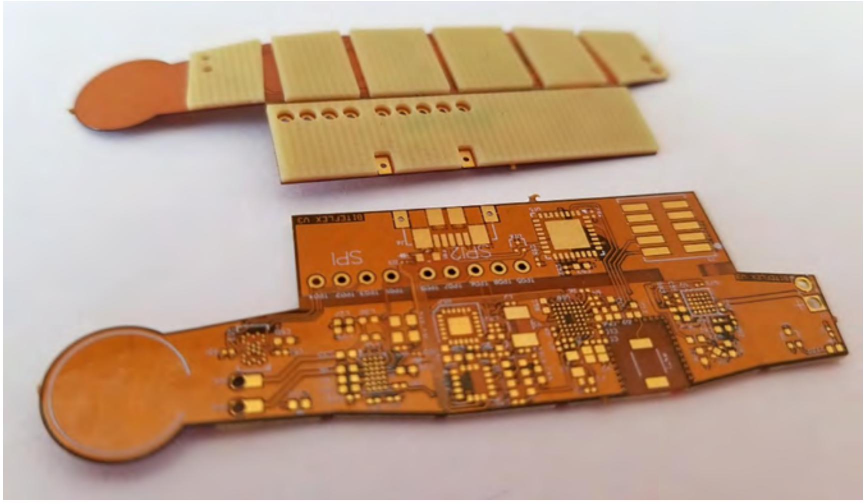


Figure 1: Four-layer flex circuit with stiffener sections on the back side to support the surface-mount components.

It is essential to understand that a flex circuit will flex in a way that means key features—such as vias, terminating traces, and sharp angles—need to be kept away from bending regions. A flex circuit is generally built with a polyimide material that is more difficult to process, so traces, vias, annular rings, pads, and spacings should be kept as large as possible. The question is often asked, “How small a trace or via can be used?” The answer is that the smaller the trace or via, the more difficult the manufacturing process will be, which ultimately will affect reliability.

On a rigid board, solder mask is applied to the outer layers to protect the copper features. On a flex board, the outer copper features are usually protected by a cover layer. Therefore, in the design process, the cover layer and solder mask layer are created the same way. The final difference in the design process is the stiffener. Stiffeners are used to add support to certain regions of a flex circuit board. The stiffeners can be in multiple regions of a flex circuit and located on either side of the board. If all the stiffeners are represented in one file, it is important to identify in the fabrication drawing which side of the board the stiffeners need to be applied. Otherwise, a separate layer will need to be created for the top and bottom stiffeners of the flex circuit board.

When additional support for a specific area on the flex circuit board is required, or protection is needed for attached components or connectors, the best option is to include a stiffener in the design. This will eliminate the circuit from moving and protect the integrity of the solder joints. It is crucial to remember that the stiffener is best placed on the opposite side of the component it is supporting. There are numerous types of stiffeners to choose from, including polyimide, FR-4, stainless steel, aluminum, etc. The thickness of the stiffener depends on how the board will be used. The thicker the stiffener, the more support it provides. If the board is being used in small or tight spaces, the thickness of the stiffener may be an issue and a thinner stiffener may be required (Figure 1).

Now that the designer has completed a flex circuit, the next task is to lay out a rigid-flex. With a rigid-flex design, the level of confusion and apprehension increases significantly. Engineers often think that the flex portion of the board is glued or somehow attached to the rigid section of the board (Figure 2). Rigid-flex is built like all rigid and flex boards with the method of layers stacked on top of layers. When it comes to designing rigid-flex, the approach is the same as the other circuit boards. The main difference is that certain regions of the rigid layers will be blank in the design file. The board manufacturer will recognize this as a flex region and will plan the board accordingly.

Unlike a rigid board, a flex circuit has a lot of variation, so having a detailed fabrication drawing to accompany the design is very important. The fabrication drawing should call out all the details to ensure that nothing is overlooked by the manufacturer. The worst thing is to have

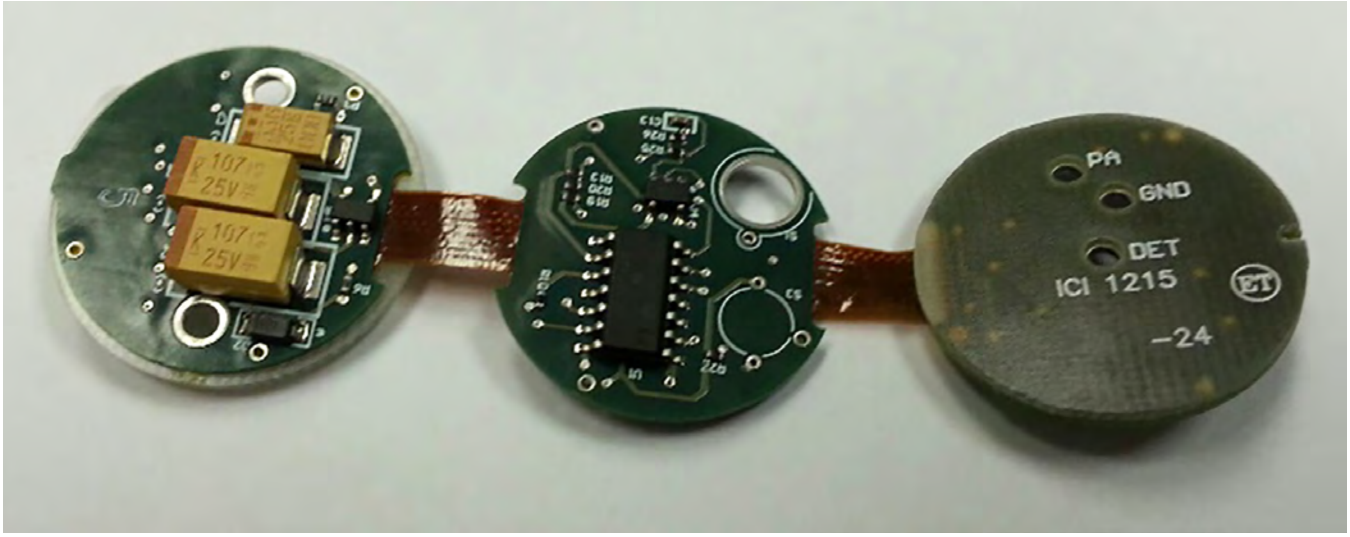


Figure 2: Rigid-flex circuit consisting of 4-layer rigid with 2-layer flex connecting each rigid section.

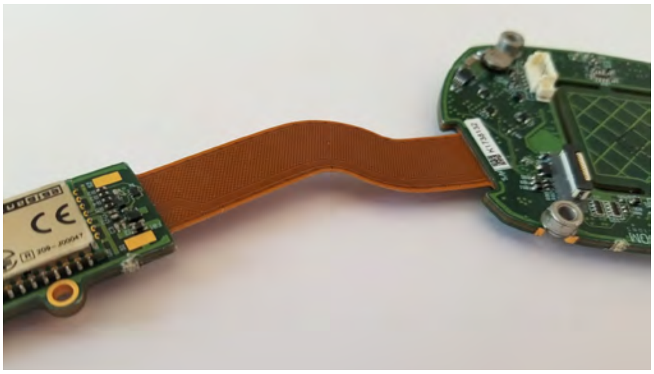


Figure 3: Rigid-flex circuit consisting of 8-layer rigid with 2-layer flex with controlled-impedance traces and filled microvias.

the manufacturer assume the requirements. Flex circuits have many moving variables, so providing as much detail as possible is critical to successful manufacturing.

Material

Material selection is important in designing a flex circuit. How much a circuit will flex depends on the type of material used to make the board. Although the thickness of the board will determine the flexibility, the specific material used will enhance the quality and overall life cycle of the flex circuit. Due to the unique design of a flex circuit, it is recommended to use the same material in the prototype and the final volume-production product. Most manufacturers in the U.S. will use polyimide made by DuPont. Manufacturers outside of the U.S. may use other material suppliers due to cost and availability.

The purpose of testing is to see how many cycles the flex circuit can withstand. Figure 3 details a general rule on a flex circuit bend radius as a guideline. The absolute way to determine how much a flex circuit can bend or how many cycles it will withstand is to stress test it.

The type of copper used on a flex circuit is another critical material. There are two types of copper, electrodeposited (ED) copper and rolled annealed (RA) copper. RA copper is preferred for flex. The copper is rolled onto the flex material and is very malleable. Thus, it is also important to call out the grain direction on the fabrication drawing. The copper grain

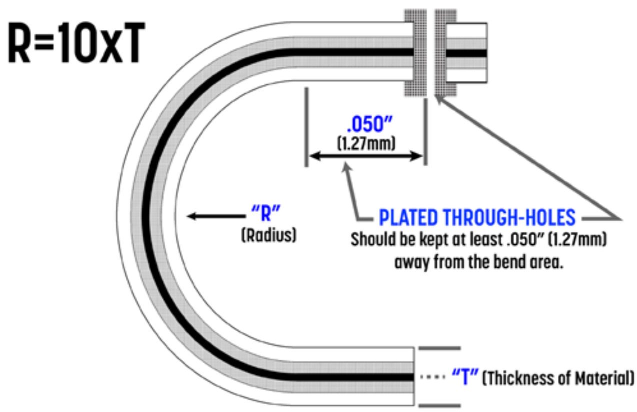


Figure 4: Flex circuit bend radius guideline.

needs to go in the same direction as the bend. Solid copper areas, such as ground planes, should be cross-hatched when possible. This will help make the circuit more flexible.

Fabrication

With the design complete, the next step is fabrication. Flex circuits are more difficult to manufacture than traditional rigid boards. Therefore, flex circuits require more manufacturing time, which results in the need for a longer lead time.

There are several issues that lead to an increase in overall manufacturing time. First, flex circuits are built using a polyimide material that is thin, fragile, and difficult to handle. The drilling of the vias and the chemistry to plate the vias is different. In addition, a significant amount of hand labor is involved with the stiffener(s) and coverlay. The result is a minimum manufacturing time of three working days for a two-layer flex circuit. With a higher layer count, the manufacturing time can be upward of two to three weeks.

Manufacturing rigid-flex circuits is very different than rigid board manufacturing. The planning and CAM-ing of a rigid-flex can easily take two to three days to perform before the board can be released to the manufacturing floor. This upfront engineering work is critical. There are many steps in the manufacturing process, and every step is essential to the successful manufacture of a rigid-flex board. One of the most important things to note is rigid-flex comes in many different stackups. It is rare to see multiple rigid-flex jobs on a manufacturing floor with similar stackups. With a rigid board, all six-layer boards are processed the same way. With rigid-flex, five jobs with six layers can be on the manufacturing floor, and all will be processed differently.

For example:

- Board #1: 6-layer board with 4-layer rigid and 2-layer flex
- Board #2: 6-layer board with 3-layer rigid and 3-layer flex
- Board #3: 6-layer board with 4-layer rigid and 2-layer flex with the two flex layers on different layers

The other difficulty in rigid-flex manufacturing is the combination of working with two different types of materials. Rigid-flex is combining rigid material with flex circuit material. Each kind has different properties that make it tricky to work with; therefore, circuit board manufacturers rarely build rigid and flex circuits in the same facility. The most common failure with rigid-flex circuits is attributed to the plating process. If the plating of the vias is not done properly, it will lead to voids, cracking, and delamination. The two different materials have different Z-axis expansion rates so that improper plating will expose poor quality.

Assembly

The last process in getting the flex circuit built is mounting all the components onto the flex circuits. For the most part, assembling components onto a flex board is very similar to assembling components onto a rigid board. The three main things to keep in mind are moisture sensitivity, flatness, and handling.

When it comes to flex circuits, moisture sensitivity is a real concern. Flex circuits are made from a polyimide base material that readily absorbs moisture over time. If moisture is entrapped in the flex circuits, it increases the chances of delamination during the assembly reflow process. It is a good idea to bake the flex circuits prior to the assembly operation to remove this moisture.

As an assembler, it is a good practice to follow this baking procedure on all flex circuits because the environmental conditions the flex circuits were subject to before assembly are not known. Flex circuits built in California will be exposed to a different environment than ones made in the high humidity of Georgia, for example. A flex circuit that has been sitting in a stockroom for a period of time will surely absorb moisture. Without knowing these conditions, all assemblers should bake flex circuits before assembly. Green Circuits' standard procedure is to bake all flex circuits for 6-8 hours at 150°C before assembly to ensure complete removal of moisture.

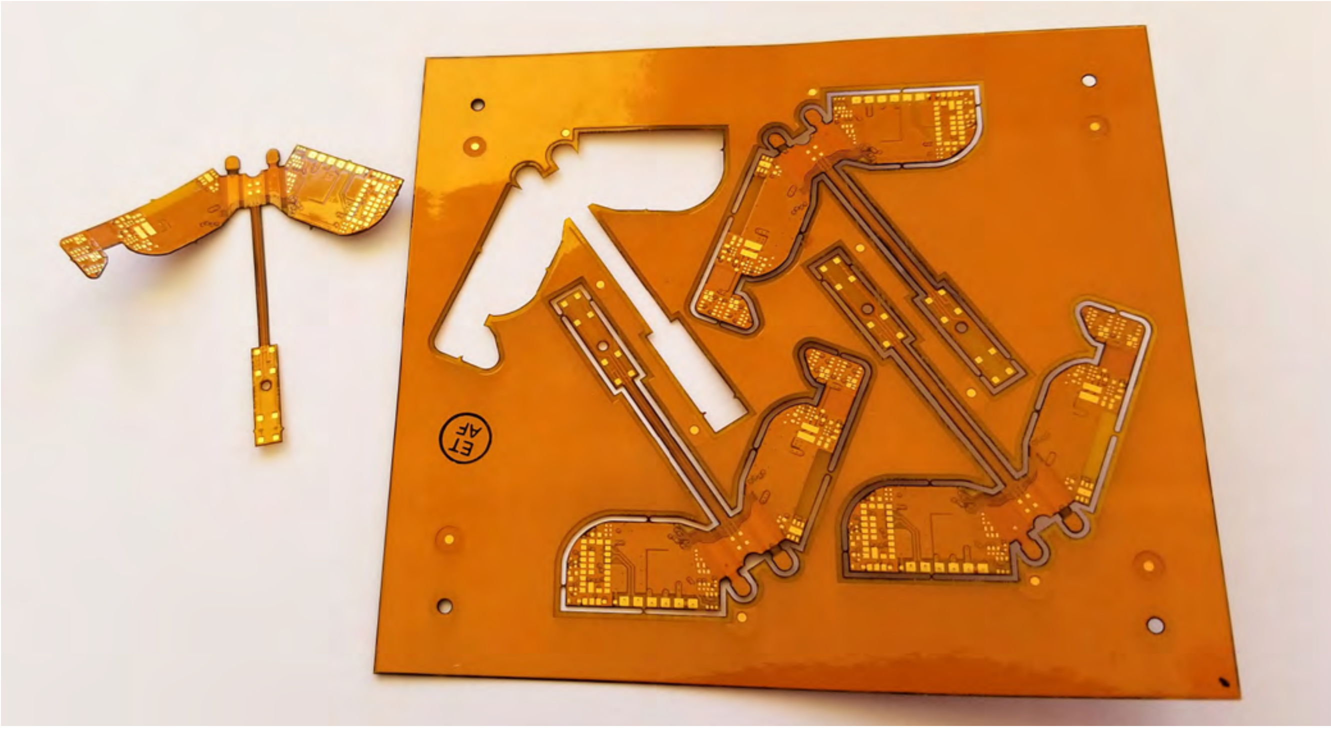


Figure 5: Odd-shaped flex circuits in panel array for ease of assembly.

One of the biggest challenges with flex circuits in assembly is flatness. Flex circuits are thin and flimsy and getting them to lie flat is always a challenge. The assembler needs this flatness to apply solder paste, place the components, and properly solder those components. Often, the flex circuits need to be attached to a carrier plate to keep them flat enough to process. A backup fixture is sometimes created to carry the circuits through the pick-and-place process. For assemblers who are not familiar with flex circuits, flatness will be their biggest learning curve.

Handling is critical when dealing with flex circuits—not just during assembly, but through the entire manufacturing process. Handling is important from the beginning of flex circuit manufacturing through to the final installation of the flex circuit. Bend radius regions need to be handled with care. Areas where through-hole components are installed need to be handled properly to eliminate opportunities for damage. Mishandling can easily tear the flex circuit or crack copper traces. Most flex circuits will naturally have an odd shape and will need to be put in an array for ease of handling through assembly (Figure 5). The flex circuit will be processed in the array and ship to the end customer in array form. The flex circuit should not be removed from this array until the final installation.

Conclusion

As electronic products become smaller, flex circuits will become more popular and common in the electronics industry. Due to the complexity of a flex circuit—including the material cost, processing time, chemistry, drilling, and handling—the cost to fabricate a flex board is higher than a traditional rigid board. Although the cost is higher, there are many useful applications for flex circuits. Flex circuits allow designers to expand their imaginations and develop more innovative electronic products. With the ability to move back and forth in a dynamic environment, flex circuits have allowed the electronics industry to be more flexible. **FLEX007**

Tuan Tran is director of customer engagement at Green Circuits, a full-service contract manufacturer for the EMS industry.

The Shape of Things to Come:

Curved, Flexible, Stretchable, and Three-Dimensional Electronics

Feature by Corné Rentrop
HOLST CENTRE

Figure 1: Roll-to-roll printing of circuit on films at a maximum speed of 60 m/min.

The seamless integration of electronics into flexible, curved, and even stretchable surfaces is being requested for several markets, such as automotive (dashboards, lighting, sensors), smart buildings (lighting facades, air quality, solar panels), medical (health patches, X-ray, analysis), and smart clothing (position tracking, sports). The requirement for products that are light, take up less space, conformable, and easily integrated into an existing design will result in an improved user interface. Additionally, the product should be robust from a cost-effective process consuming less material, and the technology should be consistent with the Internet of Things (IoT) roadmap.

The Printed Electronics Concept

Printed electronics deliver smart surfaces for applications by creating printed circuits on polymer films and utilizing traditional graphical printing techniques, such as screen printing and inkjet printing, to create the circuitry on foils in sheet or roll form.

An obvious advantage of printing electronics is the speed that can be achieved. For example, there is roll-to-roll screen printing equipment at the Holst Centre that runs at a maximum speed of 60 metres per minute, creating seamless circuits directly onto a roll (Figures 1 and 2). Photonic sintering of the metal ink allows high operating speeds to be maintained at a controlled temperature of approximately 130°C to prevent the foils from melting. In combination with roll-to-roll printing, pick-and-place assembly technology can place electrical components on the roll. Conductive adhesives are usually used as interconnects.

Crossovers and vias can be printed by alternating conducting and dielectric layers, which can maintain a PCB-like structure, only now on a roll. All polymer foil materials are suitable substrates for printed electronics. Polyes-

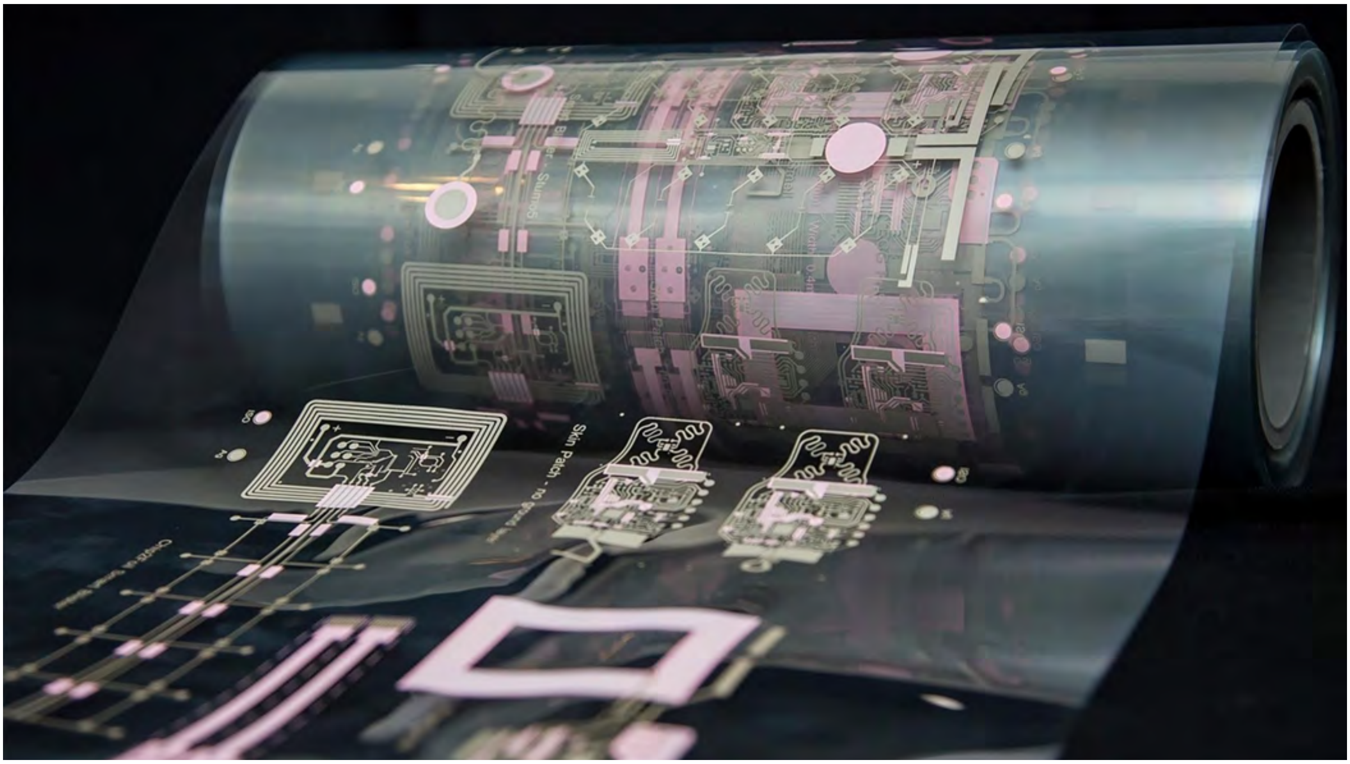


Figure 2: Roll-to-roll printed circuits on film.

ters—such as polyethylene terephthalate (PET) and polyethylene naphthenate (PEN), rubber-like material (thermoplastic polyurethane or TPU), and even paper—are known substrates for printed electronics. The low costs of these materials immediately show the second advantage of printed electronics.

A third benefit of printed electronics is the ability to change the form factor of the PCB. Foils are easy to shape into the desired form by bending, rolling, cutting, and laminating. In this way, the electronics can be integrated easily into examples like clothing, building, and on-body applications.

The prints can also be seamless, effectively with no beginning and no end, so that the size of the PCB is limited only by the length and width of the roll. LED foils are printed at the Holst Centre with a length of 300 m and a width of 30 cm. The LED foils have a pitch of 5 cm and are used as a wallpaper lighting source for indoor applications.

The Technology of Printed Electronics

PCB production is a well-established industry following highly standardized procedures and design rules, resulting in a robust and reliable hybrid manufacturing process. Replacing substrates, such as polyimide and FR-4 with a flexible film like PET, will disrupt the industry. Currently, printed electronics can realize conductivity of 10–20% bulk silver, and a feature size and pitch of 150/150 microns at industry-proven process conditions. In research, conductivity 20–40% of bulk silver, stretchable inks, and feature size/pitch of 20/20 microns have already been reported.

More and more electronic functionalities can be printed. Examples include resistors, temperature and pressure sensors, and haptic functionalities. Additional functionalities—such as microcontrollers, batteries, and capacitors—can be integrated on the flexible circuit using traditional pick-and-place technology. Interconnection is usually made with isotropic or anisotropic conductive adhesives that may be deposited by dispensing or printing. Assembly of foil-like components on a foil-like substrate will be realized in the near future. Examples of these components are OLEDs, TFT chips, and foil-based batteries.

Printed Electronics from 2D to 3D

Lately, stretchable inks have appeared, enabling the creation of stretchable electronics. These inks can survive deformation of 10–50%, and printing of these inks onto formable substrates allows a deformation of the PCB without damaging the structure.

Thin, comfortable electronics, that follow the shape of the surroundings, are created this way for integration into clothing and patches, for example. Clothing with integrated sensors, solar cells, and displays has already been demonstrated. Electronic clothing needs to be comfortable in wear and survive washing tests at the same time. Overcoming hysteresis of the rubbers and building strategies for the interconnects to survive stretching are research challenges in stretchable electronics.

In an extreme form, these materials can also be used to create thermoformable or in-mould electronics. These electronics are created on planar surfaces and then formed into the desired shape. The circuitry and graphical patterns are printed on substrates like polycarbonate. Again, the electrical components are assembled with traditional pick-and-place technology, and the whole piece is then formed into the desired shape, after which it may be die-cast to create the end-product. Thus, items such as dashboards or consumer goods can be produced in a more cost-effective way (Figure 3).

Figure 3: Thermoformed midconsole for automotive applications, including capacitive touch, OLED integration, and NFC read-out.

Figure 4: Circuitry printed on flat plate before thermoforming into a 3D product.

Lastly, the entire structure can be 3D printed. Multi-material printing allows conductive and structural materials to be combined and gives the ability to design electronics in three dimensions.

Summarizing Printed Electronics

The industry is requesting that smart functions be unobtrusively integrated into many products surrounding us. At the same time, the electronics need to be more cost effective and produced at a higher volume to fulfill these demands, especially demonstrated in IoT applications. Printed electronics may be a key enabler for IoT because they provide the best of two worlds combined—printing and discrete component assembly on a conformable and flexible material produced on a roll.

The next wave is from planar electronics to the third dimension. Stretchable electronics, thermo-formable electronics, in-mould electronics, and 3D printing is already utilized to create 3D electronics. **FLEX007**

Corné Rentrop is a project manager at the Holst Centre, an independent R&D centre based in the Netherlands that develops technologies for wireless autonomous sensor technologies and flexible electronics. Since its beginning in 2005, the Holst Centre has been involved in flexible and large-area electronics.

TOP 10

Articles and Columns from Flex007.com

1 EPTE Newsletter: Thinner and Lighter Printed Circuits ▶

Cutting-edge semiconductor manufacturers can generate less than 10 nanometer traces on silicon chips. Compared to integrated circuit (IC) chips, the fine pattern capabilities from PCB manufacturers are three orders lower while flex circuit manufacturers are generating patterns finer than 15 microns on polyimide films using a reel-to-reel process.

2 Trouble in Your Tank: Flexible Metalization, Part II ▶


Mike Carano

The main concern about electroless copper on polyimide material is the creation of a void caused by peeling or blistering. Often, fabricators resort to double-passing the circuits through the electroless copper process hoping the second pass will cover the void and prevent further blistering.

3 Institute of Circuit Technology Hayling Island Seminar ▶


Bill Wilkie

After an extreme summer heat wave had left trees dehydrated and struggling to morph into their customary display of reds and golds, the leaves were brown and brittle as the great and good of the UK printed circuit board industry crossed the bridge from the mainland of the south coast of England to Hayling Island for the autumn seminar of the Institute of Circuit Technology on September 20, 2018.

4 Standard of Excellence: Working for the Future—Partnering with PCB Vendors on Innovative Technology ▶


Anaya Vardya

The true test of the vendor-customer relationship comes when you need innovative PCBs that are not easily found in the marketplace and are so technologically advanced they require your designers and suppliers to work together.

5 Chuck Bauer Discusses the Future of Packaging ▶


Chuck Bauer

For over 35 years, Chuck has been a pioneer in electronics packaging, from 3D and system-in-package to multichip modules and nano technology. He recently spoke with I-Connect007 about current trends in packaging, the need for product designers and manufacturers to communicate, and why no matter how cool the technology is, cost is still king.

6 SLP: The Next Level of Technology ▶

As our electronic devices and machines become more powerful and as Moore's Law chugs along, things in the world of PCBs keep getting smaller. You know the drill—finer lines and spaces, thinner laminates, more layers—cram more circuitry into the same or shrinking area. Where will it all end? Or will it?

7 EPTE Newsletter: New Materials for Wearable Electronics ▶


Dominique Numakura

Technology continues to evolve, and wearable electronics are the focal point for many new concepts. The next generation of wearable products for the consumer electronics industry will create a new market with nothing but upside for manufacturers and suppliers.

8 From Trend to Game Changer: Which Technology Will Make the Cut? ▶


Hans Friedrichkeit

At the recent EIPC Summer Conference, Hans Friedrichkeit of the PCB Network gave an engaging presentation on artificial intelligence and future technologies, which was well received by attendees. Who better than Hans to offer insight on which future megatrends might truly become game changers?

9 Flex Talk: Mina—RFID, LED and What Else? ▶


Tara Dunn

Mina is a recently developed, advanced surface treatment that enables low-temperature soldering to aluminum. It is not only finding success in the RFID market, but quickly finding a home in others, including the LED market.

10 Reliability Takes on a New Urgency ▶

The advent of the autonomous vehicle and all that has been written and discussed about it has made us stop and think deeply about what reliability really means. How can we ensure that the PCBs we make are reliable and how can we feel confident that reliability will carry through to the final product—for the lifetime of that product?

For the Latest Flex News and Information, Visit: Flex007

Events Calendar

TPCA Show 2018 ▶
October 24–26, 2018
Taipei, Taiwan

PCB Carolina 2018 ▶
November 7, 2018
Raleigh, North Carolina, USA

electronica 2018 ▶
November 13–16, 2018
Munich, Germany

IDTtechEx Show ▶
November 14–15, 2018
Santa Clara, California, USA

IPC IMPACT Europe 2018 ▶
November 28–29, 2018
Brussels, Belgium

HKPCA/IPC International Printed Circuit & South China Fair ▶
December 5–7, 2018
Shenzhen, China

48th NEPCON JAPAN ▶
January 16–18, 2019
Tokyo Big Sight, Japan

IPC APEX EXPO Conference and Exhibition ▶
January 26–31, 2019
San Diego, California, USA

DesignCon 2019 ▶
January 29–31, 2019
Santa Clara, California, USA

MD&M West 2019 ▶
February 5–7, 2019
Anaheim, California, USA

EIPC 2019 Winter Conference ▶
February 14–15, 2019
Milan, Italy

China International PCB and Assembly Show (CPCA) ▶
March 19–21, 2019
Shanghai, China

KPCA Show 2019 ▶
April 24–26, 2019
Kintex, South Korea

Additional Event Calendars

PUBLISHER: **BARRY MATTIES**
barry@iconnect007.com

SALES MANAGER: **BARB HOCKADAY**
(916) 608-0660; barb@iconnect007.com

MARKETING SERVICES: **TOBEY MARSICOVETERE**
(916) 266-9160; tobey@iconnect007.com

MANAGING EDITOR: **PATRICIA GOLDMAN**
(724) 299-8633; patty@iconnect007.com

TECHNICAL EDITOR: **PETE STARKEY**
+44 (0) 1455 293333; pete@iconnect007.com

MAGAZINE PRODUCTION CREW:
PRODUCTION MANAGER: **SHELLY STEIN**
shelly@iconnect007.com

MAGAZINE LAYOUT: **RON MEOGROSSI**

AD DESIGN: **SHELLY STEIN, MIKE RADOGNA , TOBEY MARSICOVETERE**

TECHNOLOGY SPECIALIST: **BRYSON MATTIES**

COVER: **SHELLY STEIN**

COVER IMAGE: **ADOBE STOCK © PESHKOV**
FLEX CIRCUIT IMAGE COURTESY OF:
PRINTED CIRCUITS

FLEX007 MAGAZINE

FLEX007 MAGAZINE®
is published by BR Publishing, Inc.,
942 Windemere Dr. NW, Salem, OR 97304

October 2018, Volume 1, Number 3
FLEX007 MAGAZINE is published quarterly,
by BR Publishing, Inc.

ADVERTISER INDEX