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DESIGN
MAGAZINE

June 2017

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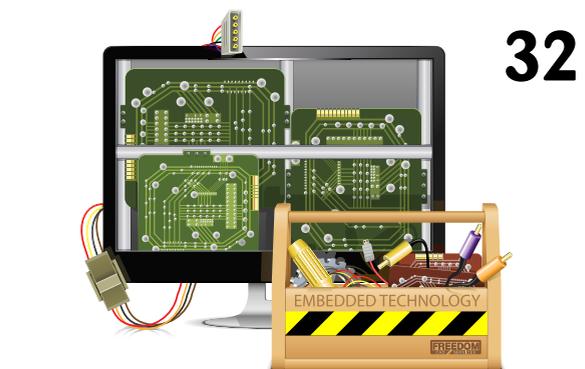
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Embedded Technology

Embedded technology is slowly becoming more prevalent, as technologists begin to take advantage of this buried technology. Embedding frees up real estate and eliminates solder joints, which are responsible for so many of the failures in the field. Embedding can also reduce resistance and parasitic inductance, which can lower EMI and improve signal integrity—all positive things for PCB designers.

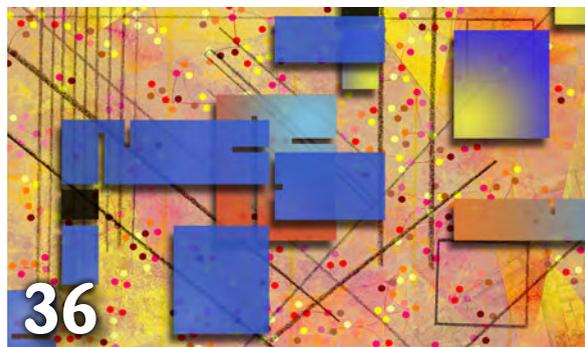


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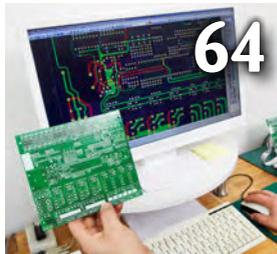
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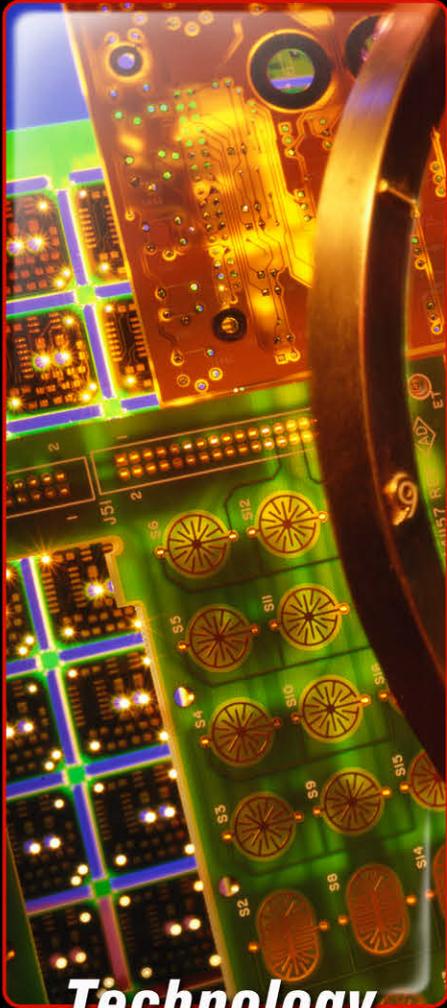
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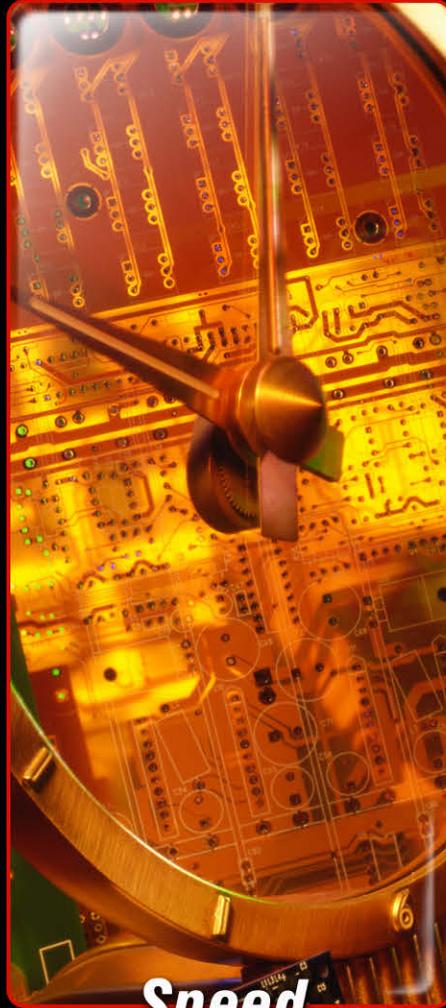
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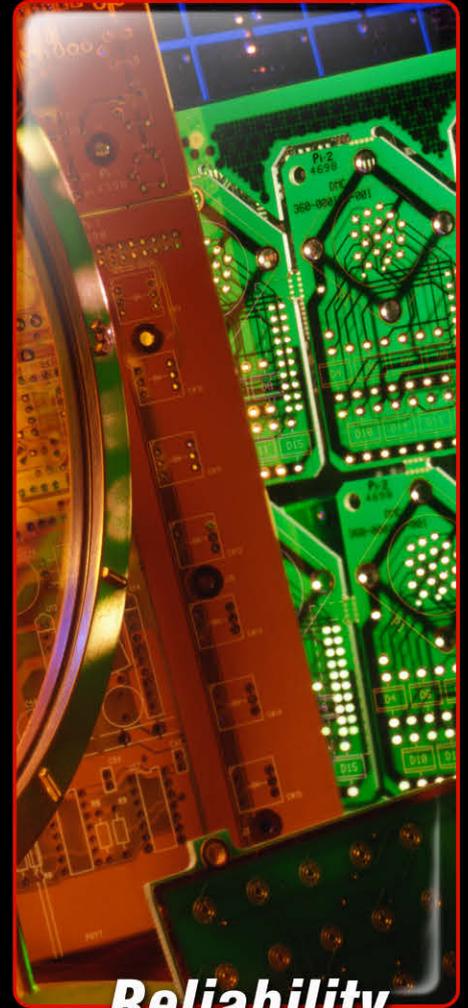
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Embedded Technology: An Idea Whose Time Has Come

by **Andy Shaughnessy**

I-CONNECT007

I've been hearing about embedded technology the entire time I've been in this industry, which somehow equates to almost two decades. When I first started covering PCB design in the 1990s, a lot of my new friends in the industry predicted that embedded components would soon be an everyday occurrence.

Some future-thinking technologists even imagined that eventually, all boards would feature embedded technology, with no components on the outside of the board. That would be one reliable board.

Embedded technology has become more prevalent over the years, especially for high-reliability applications. More fabricators than ever before can process embedded passives, and

some even embed active components. Big-name players like NASA and the Jet Propulsion Laboratory have conducted years of R&D focused on embedded passive design and manufacturing. Now, embedded components have their own IPC standard, IPC-7092, "Design and Assembly Process Implementation for Embedded Components," which is being continually revised and amended.

Still, I wouldn't say embedded technology has spread like wildfire. Even now, I have a tough time finding more than a handful of PCB designers who have experience with embedded technology. A few designers I spoke with questioned the value of the whole process. "Why would anyone ever want to spend thousands of





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dollars to embed discretely that are worth pennies?”

Embedded technology offers a variety of advantages compared to traditional component placement. It's a fairly simple idea: Take some of these pesky components off the top of the board and embed them in the inner layers of the PCB. This frees up real estate and eliminates solder joints, which are responsible for so many of the failures in the field. Embedding can also reduce resistance and parasitic inductance, which can lower EMI and improve signal integrity, all of which are positive things for PCB designers.

These are all good, except for the added cost, which I imagine has a lot to do with the fact that embedded technology is still in its growth stage. Everyone—even the military—is watching costs these days.

So, for this issue, we asked some of the top embedded experts to share their knowledge. We started off with a free-flowing conversation with Dan Brandler and Manuel Herrera of Ohmega Technology, along with our own Contributing Editor Happy Holden. In our first feature article, these gentlemen cover the history of embedded processes, their advantages and disadvantages, their benefits for PCB designers, and the future of this intriguing technology.

Our second feature is an interview with Scott McCurdy, director of sales and marketing

for Freedom CAD. Scott discusses various types of embedded technology, including buried capacitance, planar magnetic boards, and components placed inside cavities in the board. Next, our columnist Vern Solberg takes us through the current state of embedding resistors, capacitors, and inductors, and some of the roadblocks that embedded technologists must contend with. Finally, Dora Yang, and engineer with PCBCart, discusses the design and fabrication process for embedded thin-film resistors, and their numerous applications.

We also bring you columns by our regular contributors Barry Olney of In-Circuit Design, John Coonrod of Rogers Corporation, Dave Becker of All Flex, and Alistair Little of Electro-lube.

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Andy Shaughnessy is managing editor of *The PCB Design Magazine*. He has been covering PCB design for 18 years. He can be reached by clicking [here](#).

Amazing Spintronics

For cell phones, computers, and other electronic devices, a major shortcoming is the generation of heat. The energy loss significantly reduces the device efficiency.

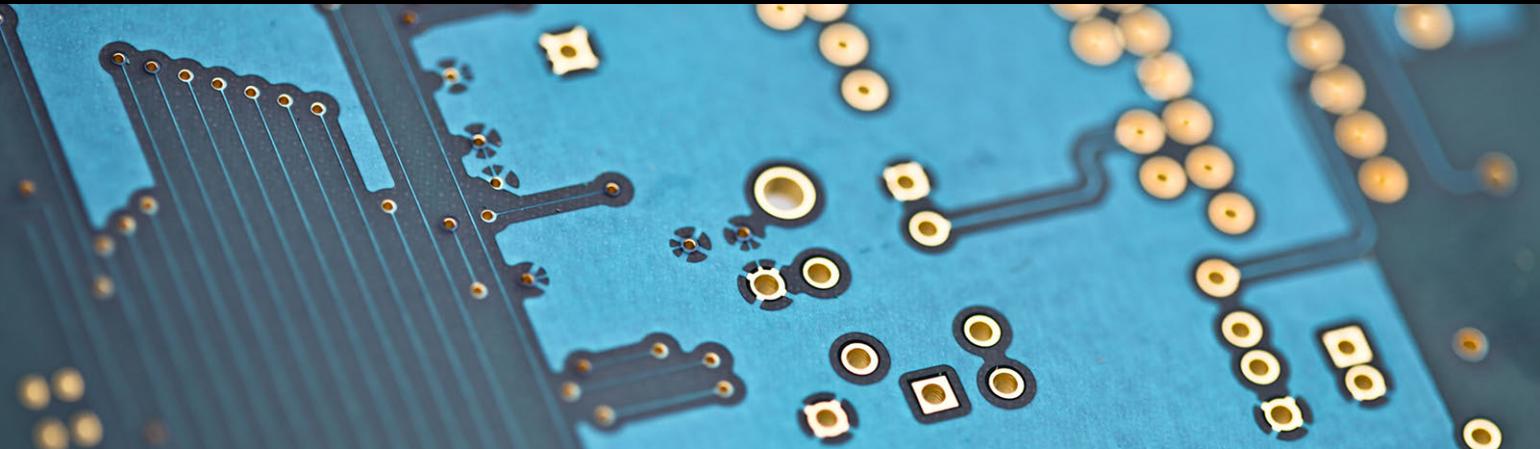
Spintronics' promise is to eliminate this energy loss. It does so by just moving the electron spin without moving the electrons. Using design strategies such as those identified by this research could result in highly energy-efficient spintronics to replace today's electronics.

An important obstacle to realizing spintronics is the amplification of small spin signals. In conventional electronics, amplification of an electron current is achieved using transistors.

Recently, researchers at Johns Hopkins University demonstrated that small spin currents can be

amplified by inserting thin films of antiferromagnetic insulator materials into the layered structures, effectively producing a spin-transistor. Scientists used thin films of antiferromagnetic insulators, such as nickel and cobalt oxide, sandwiched between ferrimagnetic insulator yttrium iron garnet (YIG) and normal metal films. With such devices, they showed that the pure spin current thermally injected from YIG into the metal can be amplified up to ten-fold by the antiferromagnetic insulator film.

The researchers found that spin fluctuation of the antiferromagnetic insulating layer enhances the spin current. They also found that the amplification is linearly proportional to spin mixing conductance of the normal metal and the YIG.



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A DEEP LOOK INTO EMBEDDED TECHNOLOGY

by **Barry Matties and Patty Goldman**
I-CONNECT007

In preparation for this month's magazine, we set up a conference call with the goal of uncovering the challenges and opportunities related to embedded technology. Invited were a handful of the industry's heavy hitters in the embedded world: Retired technologist and I-Connect007 Contributing Editor Happy Holden, and Ohmega's Technical Director Daniel Brandler and Design & Test Engineer Manuel Herrera. This informative, comprehensive discussion focuses on the state of embedded materials and components, today and into the future, as well as a variety of promising processes.

Patty Goldman: Gentlemen, thanks for joining us. Some of the things we want to learn are: What's going on? What's the latest? Additionally, what are some of the things that you think that your customers want to know?

Dan, Ohmega Technology has been doing embedded components for over 30 years. Can you provide an overview of that work?

Dan Brandler: Ohmega Technology primarily makes materials used in embedding resistors, planar resistors, even surface resistors under the

solder mask, but mostly it's a multilayer structure. We electrically deposit a nickel-phosphorous alloy, which is the resistor material. It's been around since World War II, so it's a very well established material. We electrically deposit it on standard ED copper foil of different levels of roughness, which will be discussed later in the conversation, and we supply that material to either laminators for PCB or microwave applications or to board shops who make their own laminate and PCBs with the embedded resistors. In some cases, we subcontract laminates out to companies. But our primary business is just applying the resistive copper foil and we've been doing that for a long time. We're not the only ones doing it; there are other alloys out there like Nichrome, but we're the oldest.

About 30–40% of our business is aerospace defense, things like power dividers, microwave applications for satellites, phased array antennas, and microwave absorbers. That didn't used to be the case, but the majority now for commercial use is mainly for sensor technology, particularly in cell phones. I would guess almost all of you or at least certainly half of you I'm speaking to right now will probably have cellphones with you with our resistors in it. Our resistor material is in the largest American cellphone manufacturer's products. I'm not supposed to

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use their name, but we're designing their next model. As these phones increase they use more and more microphones. The original microphone was designed to listen to your voice, but there are microphones to listen to noise, and there are microphones in the speakers and in earbuds. All of these sensors are MEMS modules that use resistors.

They're simple boards, basically two to six-layer boards that have one or two layers of Ohmega in our case. These are used as part of filters which means they have capacitors embedded as well and most of the time, I'd say the clear majority of it you will have different layers. Let's say we have an OhmegaPly layer and a capacitive layer, and a capacitive layer might be 3M C-ply or it might be Oak Mitsui as a capacitive layer in a separate core. However, we do have a joint patent with Oak Mitsui for a combined product, which means the same core has both the embedded capacitor and the resistance. There are some advantages to that. The reason it's not more widely used is that it's a more expensive product and therefore the economics are rather working against us. Plus, there are some difficulties in the way you test capacitors; it's a lot different than the way you test resistors.

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“So for now, most of these applications, particularly in cellphones, is at the capacitive embedded layers and the resistive embedded layers are separate and can be handled and processed separately and then all laminated together.”

.....

So for now, most of these applications, particularly in cellphones, are at the capacitive embedded layers, and the resistive embedded layers are separate and can be handled and processed separately and then all laminated together. This totally blindsided us 10 years ago, by

the way, and that has become the biggest part of our business. Originally our core technology was the high-end, very expensive military aerospace—all those things. That's what we thought was our main application. Telecom and advanced high-end file servers would be the main part of our business. But what has happened is that suddenly these low-frequency applications came along, and then the audio. With 100 million cellphones, that became the largest part of our business, mostly being exported to China. Our materials are shipping to the Far East all the time because there are so many board shops and so much assembly work done in the Far East. We export primarily to China, but also Taiwan and Malaysia and various Pacific Rim countries.

The technology is well established although the applications are new; it's standard print-and-etch technology. Board shops already have almost all the equipment, although there are a couple that might need a nickel strip tank, or their testers would have to be different. But basically, it's the same print-and-etch technology that they all use. The first etcher we don't care, they might use cupric chloride which they would have to use if they used Nichrome. Also, the big thing in miniaturization is using laser direct imaging. Almost none of our PCBs are laser trimmed. Close to 90+% is “as is,” which means they have very precision printing and etching which is sufficient to hold the necessary tolerances. We're not a big fan of laser trimming; on the other hand, we love direct imaging, either laser or LED technology.

The imaging technology has improved and our product has improved to allow very miniature resistors like 50-micron (2 mm) wide resistors, 2 mm by 4 mm or 8 mm and holding a reasonable tolerance. That's the new, biggest thing. We saw this coming, but seeing it didn't necessarily mean we had all the answers to it. There were two worlds: there was the world of high-speed digital and there was the world of RF microwave. In the world of microwave, the gigahertz technology needed very smooth conductors because of skin effects, and the smooth conductors lowered the resistance. Since we control sheet resistivity, that's why it's about resistance, not thickness. What happens is the conductors get smoother and smoother and

that drives down the thickness of the resistor material, so it becomes thinner.

The identical alloy that you had 10 or 20 years ago, say at 25 ohms per square cm would be 0.4 microns thick; now it's down to 0.2 microns and on its way down to 0.15 microns. The only difference is the surfaces are very smooth and it's driving down resistivity. At the same time the question is: how do you improve the bond strength? Because when you get these very smooth surfaces, the bond strength starts dropping and then you're subjecting the PCB to thermal shock and so forth. The lower bond strength then turns into a reliability issue, so these two worlds are kind of like colliding. The high-speed digital is getting faster and so is the RF. Basically the bottom line is we all know about Moore's Law, but there's also this frequency thing. If frequency is increasing, it is inevitably driving down the thicknesses of these embedded layers because of the need for smoother and smoother conductors.

And that's where we are now. We're looking at copper foils that we're going to be plating on and we're looking at chemical solutions, because it's not going to be mechanical, improving bonds so that we can use these very smooth conductors. We have an R&D program now directed at that, and it's what we think is the next big thing coming along. I don't see that stopping at all.

Meanwhile we are very busy; 2015 was our record year. There was a slight downtick last year, but this year we think we'll beat that. Certainly, year-to-date, we're in record territory in terms of business. Mostly driven by the combination of aerospace defense increases and the commercial has also increased. It's not that they're going to sell that many more cellphones, but we're in the China market as well as the U.S. market, and they're using more microphones per phone. Plus they're using more layers, like one to two, but to go from one to two layers per PCB doubles it right there. We're really seeing a huge upswing in these applications.

Matties: For the increase, if I'm hearing you right, you're saying that people are coming in and doubling up on your material in the same application for the same board?

Brandler: Yes, two things are happening: more microphones for noise cancellation to improve sound fidelity; and second, more layers for the same reason of resistive layers and capacitors. And we're still pushing on this combined product, although most of the capacitive layers and resistive layers are separate. But what you must have is both capacitors and resistors to create a filter and part of the problem of miniaturization is, if you look at a laptop, the high-speed end of it is rather far away from whatever audio stuff is going on, and the digital is in the middle. But as you then squeeze it down to the cellphone size, things get a lot closer together, and if you squeeze it down further to an ear bud, now they're right on top of each other. And all that RF interference is going right through the digital circuits.

“ This is where signal integrity, this is where the fact that things are all on top of each other at very high frequencies, there's all this crosstalk and parasitics going on that must be dealt with. ”

You must have a way of dealing with that and one of the ways is to put the capacitive layer right below the resistive layer to eliminate noise. This is where signal integrity, this is where the fact that things are all on top of each other at very high frequencies, there's all this crosstalk and parasitics going on that must be dealt with. As a result, the inevitable drive for higher densities and higher frequencies has caused the need for more applications of these embedded paths and layers, both resistive and conductive and capacitive. So it's really a design thing.

I would say the driver for us now is higher frequency, smoother copper. There are also some issues in the supply chain. The standard coppers are available in the States, but some

of these ultra-smooth coppers are not made here. We have to go to Asia to get some of these super-fine things, and we're competing. The problem we see in the marketplace with getting copper foils is that the lead times are starting to lengthen and what our suppliers tell us is that fine line etching is really using up thin material. But even more so, these energy storage batteries, not just for cars but for homes, for storing solar energy or whatever energy require a lot of copper.

They're sucking up all the copper in the industry and now we're seeing lead times out 6–8 weeks where before it was a couple weeks. The lead times are going up at the same time that our volumes are going up. I don't know where that's going to end, but every time Tesla builds a new megaplant somewhere, believe me, they're going to use a lot more copper. I don't have an answer to that question except that so far, we're dealing with it and we're keeping up with the demand. We'll see how that goes.

Matties: What sort of increase in copper price do you expect we'll see this year, 30%?

Brandler: I have no idea. What we've seen so far is an increase in delivery and the lead time is being pushed out. But you're asking the wrong guy, I'm the technical guy. I don't really get involved in economics but you asked the right question. I think it's inevitable that's going to happen. But the lead times being pushed out tells me they're struggling with capacity issues which means the price is going to start climbing.

Matties: Thank you very much. Happy, do you have any thoughts or questions on this?

Happy Holden: Well, it's an interesting topic that's been around a long time. One of the problems I always felt with the material supplier is that they always had the cart in front of the horse. In other words, they were always introducing and pushing new and better materials but had failed to establish any kind of cost tradeoff. The first step is always providing some cost trade off. In other words, everybody asks how much is this going to save us or what benefit is

this? And since they never really produced any kind of model or software to allow people to do a cost trade off, those that experiment with it got burned severely when they found out how expensive it was versus conventional surface mount and even embedded surface mount.

So the industry still has fundamental problems that it can't answer the question of how do I benefit from this? There are some companies like in the aerospace industry, because of reliability and temperature and/or size or weight, they have to use that and they've been a user for 35 years. The mobile phone people are using it for the same reason and that is size and weight as well as performance advantage. But that's not the North American market too much or the rest of the world, everybody is still standing around waiting saying, "Show me the benefits." And I don't mean a whole bunch of bullets about how great it is, because we know that's only part of the picture. Show me the cost model.

Prof. Peter Sandborn at the University of Maryland developed software for MCC and Savantage Inc. that does cost tradeoffs of embedding components, either discreet or process. And it does it iteratively as it redesigns the board to find the sweet spot, where if you do it this way, you have this many resistors or this many capacitors or this size, you can reduce the size so that the material cost drops and you'll make money. But that's not available, or nobody's commercialized that or made it available for free. We're all still stuck with that first question. Then comes the second question: What are the characteristics available of the material? Then comes, how do I design this, what are the design tools out there, and how do I use them? The fourth question is, how do I fabricate this? Is it a drop-in, or do you have to add special processes and things like that?

I've put embedded ICs into active production and shipped tens of millions of the units. The fabrication of some of these things is a lot more difficult than many times what's advertised, especially if you're doing active ICs not just passive devices.

Brandler: I definitely have a different point of view from Happy. Ten or 15 years ago, when I

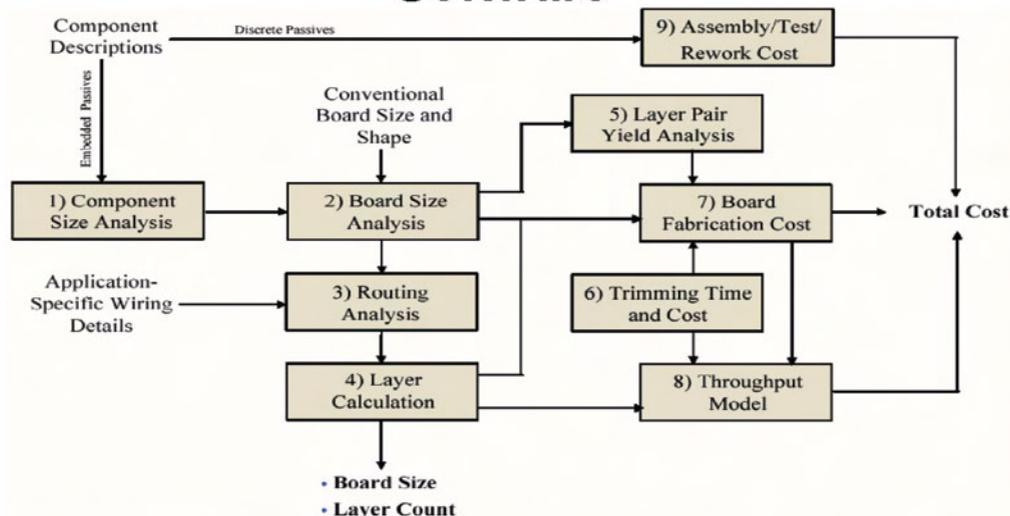
first came here I would agree with what Happy said. I think that was right, there was certainly a cost issue and tradeoff and how many resistors per square inch you need to replace surface mounts, but I think we've moved on. Let me address some of the issues he raised. First I want to be clear, our intent was never to sell OhmegaPly as a way of saving money on surface mount components. That model would not fly. Our main thing had to do with performance and density and miniaturization and signal integrity, and so forth. Yes, there were some cost adders at the worst possible place—with the material, because we're basically a material supplier. The reason we're still here, being the most expensive product at that time, was because of other technical reasons why people used them. Certainly, if you're building a satellite that's going to cost a billion dollars, you don't care if you have to spend another \$100,000 to make it work.

But here's what we did and how we addressed those issues. First, we did address cost tradeoff issues, in terms of providing spreadsheet programs with the goal of selecting a single layer. The single layer is the lowest possible

cost adder; if you have to use two layers, say one for the terminating resistors and one for the pull-up and pull-downs, you just doubled that cost-adder. So our goal was to provide a single layer. We would have customers give us the bill of materials, we'd go through the resistors and say these are the ones you leave on the surface, these are the ones you can embed using the terminating resistors. For the applications, if we had a BGA we could do something with a BGA that you couldn't do with a surface resistor, mainly terminate every lead onto the footprint of the BGA and free up a lot of space on the surface. All these were ways to reduce cost. The cost wasn't the main thing; the main thing was you had to terminate every lead.

The other thing we did was, when some CAD designer ran out of room, the only way they're going to get more parts or more leads was to add layers, and adding layers was the fastest way to increase cost. Using embedded layers was an alternative to adding layers so you wouldn't have to route back to the surface or go down the multiple layers to escape the array. I think, Happy, you did some of this work when you talked about resistor density limits

Embedded Passives Cost Analysis Software

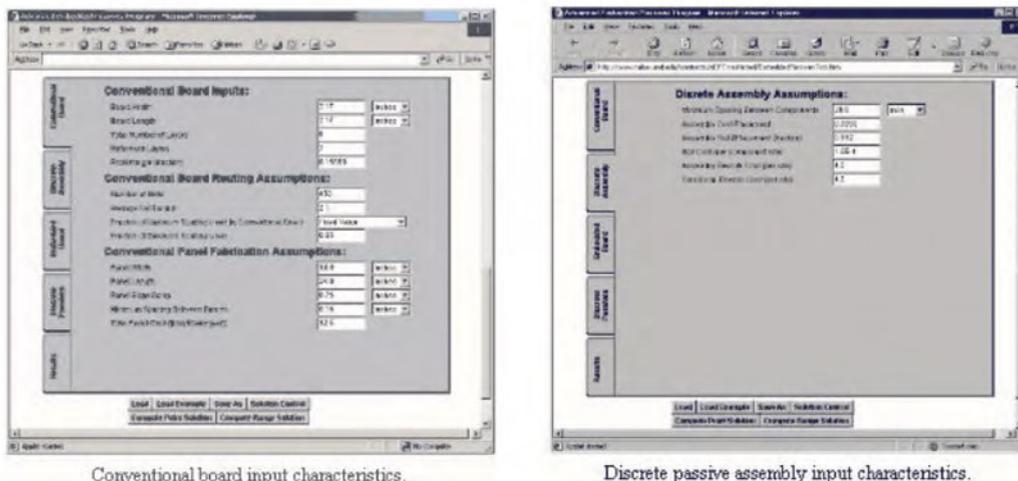


Developed jointly by NIST Advanced Embedded Passives Consortium and the CALCE Electronic Products and Systems Consortium at the University of Maryland

Source: www.enme.umd.edu

Figure 1: Cost analysis software developed by NIST and CALCE.

Embedded Passives Cost Analysis Software



The tool supports full Monte Carlo analysis, allowing each input to be optionally described as a probability distribution.

Figure 2: Sample input for embedded passives cost analysis software.

and things like that and crossing that density level, how many IOs per square centimeter or whatever. On one hand was conventional surface mount and the other was embedded. We did that too; we developed those same kinds of models.

The other thing that took place was miniaturization, for example in cellphones. These costs that you're talking about are basically area pricing. As the resistors got smaller and smaller, the amount of material that's in a cellphone is minuscule. They're so very small that a ten-inch by ten-inch material would be enough for thousands of cellphones. Miniaturization also made this economically feasible. Believe me, the cellphone manufacturers have very tight production cost schedules. The combination of miniaturization and the use of resistive layers is to avoid adding more layers or to go to more complex-type printed circuit, like HDI. If you could postpone going to HDI by embedding a layer, then there is a savings. It's not a surface mount versus resistor layer model. You're looking at the total system cost of reducing that and cost tradeoff.

In terms of design tools and fabrication, one of the things we do is provide excellent

tech support all over the world. We have very good distribution representation in Asia. We can go in and provide all kinds of tech support both in the initial phase in the design, working with the CAD guys and the CAM guys. There are all kinds of unique applications. There are resistors you wouldn't recognize as resistors. Also, my job here is to give away the process technology and to provide help with processing. Fortunately, most of that is standard and they don't really need a lot of new equipment. If they can do controlled impedance they can make resistors.

But that's an area we're doing really well on—maybe I'm biased, of course. But we do provide design support and tech support, and we provide it all over the world. Now is the cost of the materials, the laminate, going to go up? You bet it is. But the tradeoff in how the design changes at the end of the line, and I agree that's very difficult to model, but an old break-even chart with how many resistors per square inch, I don't consider that relevant anymore. We're in an area now where we're being used because there's no other way to do it. That's what is driving this whole thing and there are tradeoffs and costs.

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Example of Tradeoffs (Board Price vs Number of Embedded Resistors)

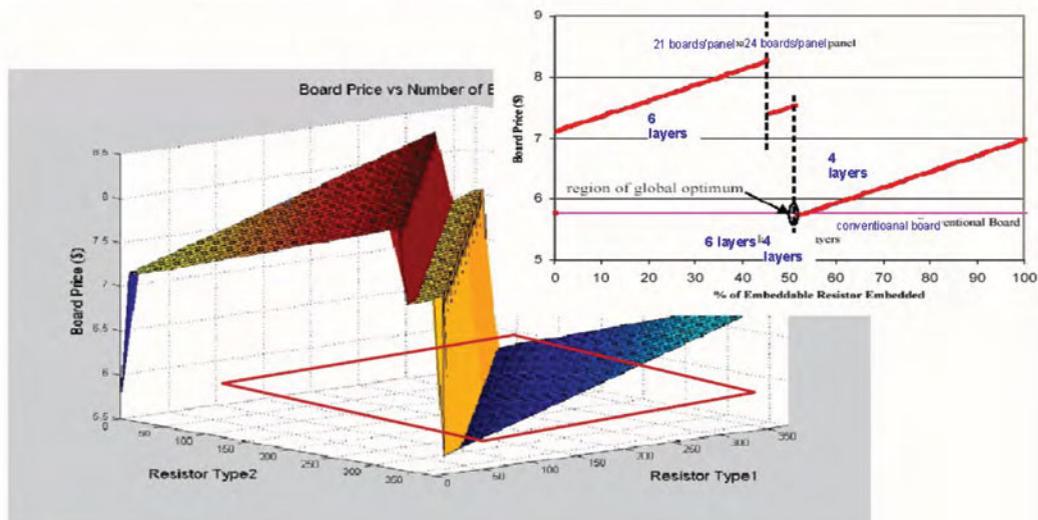


Figure 3: Showing the effects of embedding resistors on the board price for a 5.1 x 15.24 cm board with 500 discrete resistors of type 1 and 400 discrete resistors of type 2. The optimal board price is realized at ~52% of embedded resistors.

Matties: So the physical parameters have forced them into this model, not the cost.

Brandler: Partly physical parameters and partly really high-speed, eliminating parasitics. There are no inductive reactants like you have with a surface mount device. The technology is what's driving this and the cost is sort of following it. Nobody wants to add costs, I agree. There's no designer in the world that wants to come up with a new design that adds cost to the substrate; that's the worst place to add cost. But the reality is, when they see the alternatives that they have to do to accomplish the design, then it looks more attractive. That's basically the issue, but I think mostly that's a 20-year old issue. Now we're well beyond the realm of surface mount versus resistor tradeoff.

Holden: I agree with all that. Miniaturizations and various kinds of modules that become BGAs that get attached is an area, but that is not a predominantly North American circuit area. That's limited to those things that demand that miniaturization, like mobile phones but most of the industry doesn't demand that much miniatur-

ization. And I haven't really seen an article that I can recall that talks about the performance and the miniaturization aspects of embedded components. There just haven't been any articles that talk about this.

Brandler: We can send you some. We're going to these trade shows and exhibitions and publishing these things all the time. But the one thing I also want to say is on the whole issue of North American versus Far East. The North American market for us is primarily aerospace defense. Our competitors are in the same market too, it's not just us, and what is driving that are things like power dividers and other similar RF electronics designs that allow them to make all these networks and such. Really, you could do it with strip resistors and things like that, but this has been around for a long time and the new microwave horns and things that are using absorbers to improve the signal integrity by absorbing all the stray signals and shielding and these are applications where normally you want to get heat out of the chip, but if you talk about space sometimes you want to put it in.

All these kinds of applications are military aerospace that are using this for entirely different reasons. They're not very cost sensitive because compared to the cost of what they're doing this is negligible. Again, reliability, performance and such are the main things that they're looking at and the fact that it costs a little more than a surface mount board or something isn't a big deal for them.

Matties: What sort of challenges does this place on designers?

Herrera: Well, I think a lot of the questions that I get are what tools can we use to design this in? And I know Altium and some of the Mentor Graphics tools have embedded functionality built in that designers can use if they want these resistors to be embedded; the tool will help them embed them. Then there's the method that I'm more familiar with, which is the manual method, where you're sizing resistors based on the geometries and the power requirements or tolerance requirements, and then manually putting them in the artwork that way. But I think for designers, if they have the idea that they want to embed, it's reaching out to the tool provider that they're using and getting resources there or coming to us to get resources to figure out how to do it, and in addition to that we will also work with the board shops.

If it's a board shop that's not familiar with processing our material, we'll get involved and help there, but for the most part we have a pretty big catalogue of board shops that are processing our material, that are familiar with it, and the support there is also great for the designer. For example, the board shop will adjust the artwork to compensate for processing factors. This is commonly done to hit controlled impedance targets and usually happens behind the scenes. The experienced board shops also understand how changes in geometries affect the finished resistor values. This becomes more critical as geometries become less than 0.010" (0.254 mm).

Andy Shaughnessy: It does seem like the tools have gotten better, though, because I remember there used to be no embedded design functionality in any of the EDA tools for PCB.

Brandler: I was at the last IPC conference on this and they moved on from passive to active. [See Figures 4, 5, 6 and 7.] That's the next big thing: embedding active components. And all the issues we had to deal with passives, like what happened with the lamination destroying some components? Well, it'll destroy the active component too or the interconnects anyway. There's a whole new world with actives, but we're still there. The passives are already established as being embedded. Then there's the introduction of highly precise printing and etching using direct imaging, where you could do compensation and you don't have to laser trim to hold tolerances. As you eliminate tolerance as an issue then, what Manuel said becomes true, power starts becoming an issue when you get extreme miniaturization.

Even though we normally don't think of any power being required, for things like terminating resistance down to a few milliwatts or whatever, it starts to add up. And then they get smaller and smaller and we have to deal with a temperature rise. This then becomes another constraint that is part of it. The other constraint we have to deal with is ESD. ESD was a big deal particularly in the cellphone business when you're talking about human body model; can it pass 8,000 volts? Remember I said it was getting increasingly thinner because of the high frequency? Well, then ESD endurance becomes less and less. Now we have to design for ESD. At what voltage can you test these at and expect them to pass? And so that's been incorporated in our latest software.

Our latest spreadsheet model now includes, besides power and tolerance normative value for the minimum size, we're also saying what's the minimum size for the voltage you're going to be testing on ESD. When we talk about direct, that means directly applying the ESD to the module. These are new challenges that we didn't really have a big problem with before, and because of this, it also changes the sheet resistivity, because the lower the sheet resistivity the thicker it gets. Maybe it doesn't pass 8,000 volts at 50 ohms per square, but it does pass 8,000 volts at 40 ohms per square.

What this has done for us is created a whole new range of products we have to add and we

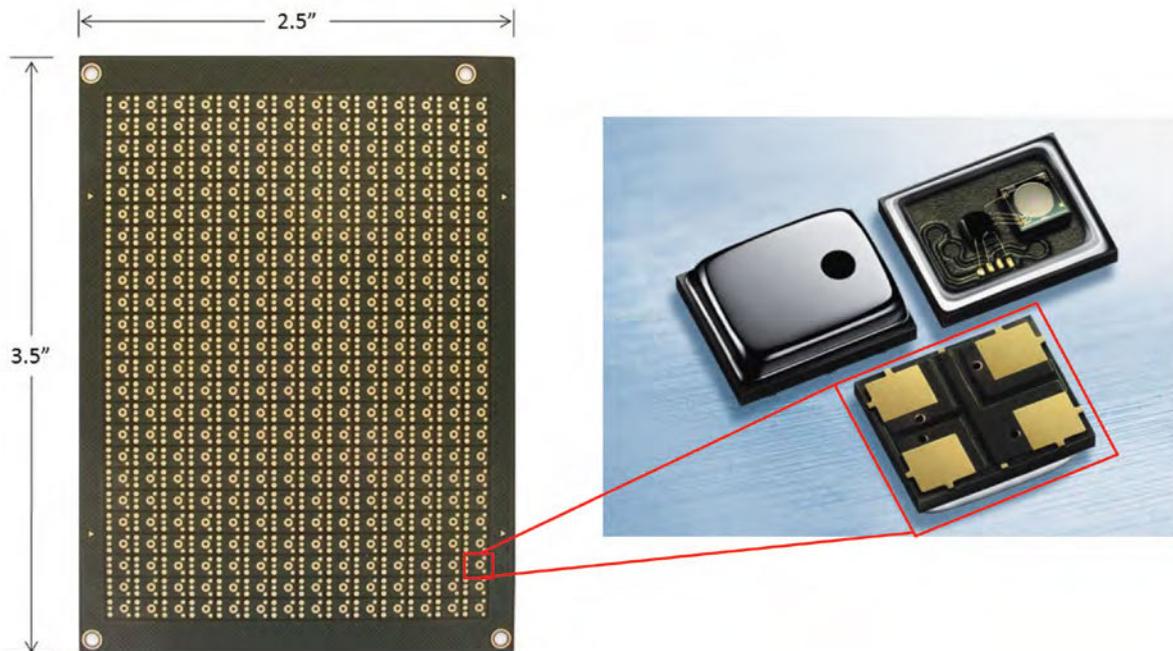


Figure 4: MEMS microphone sub-panel with projection to module shown.

offer different ohmic values. In terms of copper, most of the time half-ounce copper dominates the whole world, but now we're supplying a significant amount of 12-micron copper. Why? Because for fine-line etching they want thinner copper. We're seeing some 5-micron but that requires a carrier we don't like. It's very expensive. If you think the costs are high now, that's really expensive. Also, it's not available in the United States so we have to get it from Japan or Taiwan, whereas 12-micron copper is made here in the U.S. Because not only do you want conductors for high frequency, you also want it for fine line etching.

We're seeing smoother surfaces and thinner coppers. All this of course is still half-ounce so what that means is when we add six or eight products now we have 20 products, and since we basically ship from stock, rather than manufacture to order because the lead time would be too long, it requires us to now inventory a whole wide range of products that we didn't have before. That's something else that we're dealing with. Fortunately, we're in very large facility here so we're able to do it.

Matties: This is really interesting, especially when you mention embedding active. Happy,

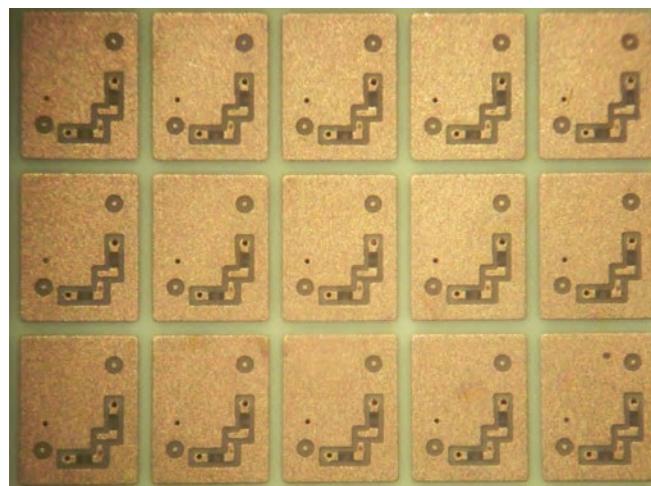
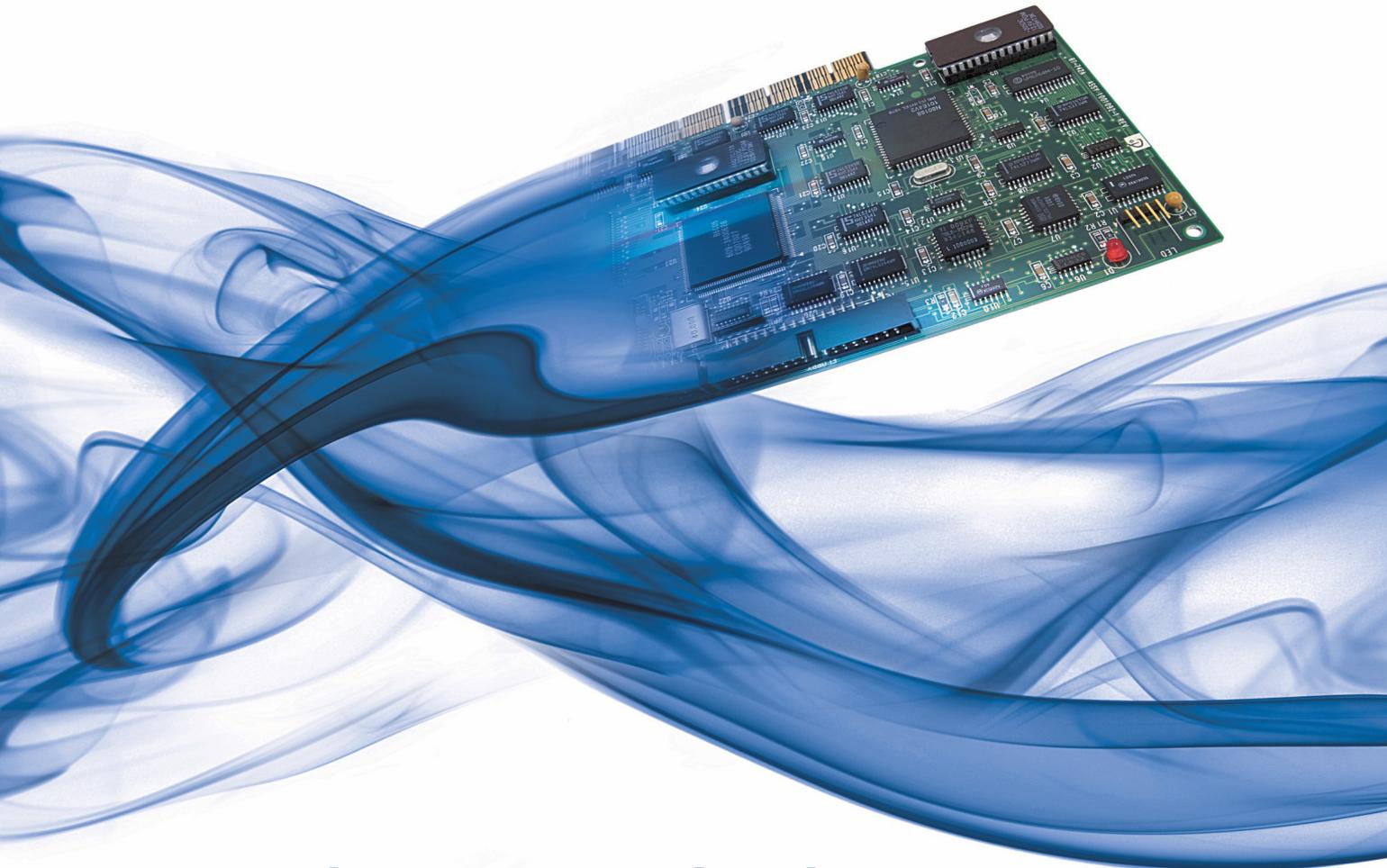


Figure 5: MEMS microphone PCB array with exposed planar resistors.

do you have any thoughts around that side of this?

Holden: Well, we had to spend an awful lot of money to make embedded actives work because the little secret that they don't tell you until after you sign the licensing is that you have to have a yield of 99.7% on very complex HDI, otherwise you throw away more money in the ICs than



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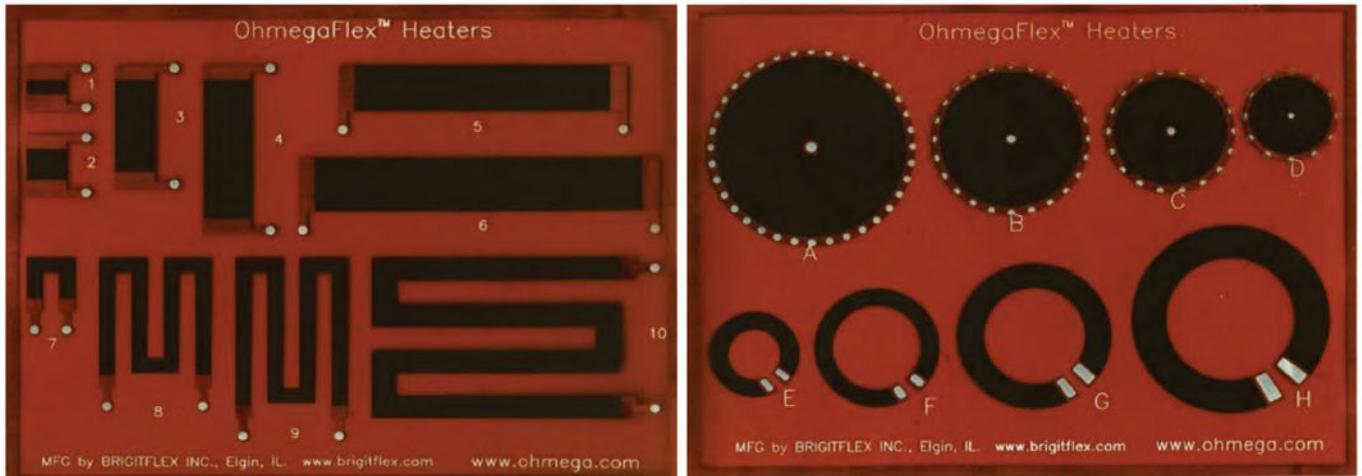


Figure 6: OhmegaFlex rectangular and circular heaters.

you save. We had to switch to a third facility in Northern China, which is basically employees made up of North Koreans. And there we found the discipline it takes. You can do this in Japan, but outside of Japan nobody else can really make this thing work except for these Korean workers and we got to 99.85%. Now we're shipping 10,000,000 modules a month that use both embedded capacitors and resistors and ICs because they're so small. The surface is taken up with an active device either with the MEMS microphone, the optical sensor for the camera, or the antennas for the WI-FI, and things like that. But this is all mostly dedicated to the mobile phone market, which is great, but most of the readers of The PCB Magazine aren't in the mobile phone market.

Matties: Aren't those also in applications like hearing aids and other medical devices?

Herrera: We have seen them in applications where they're calling them micro-fluidics or micro-fluids, where they need to heat up a liquid and move it through these small channels on a MEMS sensor. That's an application in the medical field and that's the one that comes to mind. Others had medicine delivery applications; the heater would heat up the medicine and help push it through a patch.

Brandler: Since resistors are heaters, we see a greater demand for, usually, flex heaters in

which the dielectrics are extremely thin because you want the heat to go right through it. I'm sure it applies to our competitors as well, because it's very thin; the advantage of using these as heaters is that it takes very little power to get a very fast temperature rise because there's so little thermal mass—you can get a fast temperature rise even though there's not a lot of heat. There are applications for that and it's not really big, even though Manuel is involved with designing this. I would say in terms of percentage of our business it's very low compared to the other things we were speaking about.

Herrera: Maybe the reason it's gaining a little traction is due to the way these devices are being built. They're more modular. Imagine a motherboard for a computer—this has actually been done—with embedded resistors, say 700 embedded resistors on the whole motherboard. Now, our process is a subtractive process, so all the area that's not being used as resistors is basically etched off; essentially 95% of that layer is gone and only 5% is left for the resistors.

Since they're all termination resistors, we decided to make a small interposer board and put all the termination resistors on it. Now instead of getting four motherboards on a panel, we'll get hundreds of these small interposer boards and that will be used to attach the IC; then that'll go on to the motherboards. What they did is essentially use a lot more of the resistive material. And the same idea is what we're

seeing in the MEMS microphone market—the concept of making it a module. You have tens of thousands of these little PCBs on a panel and each one of those PCBs has two resistors; you’re basically using 30% of the resistive material now. I’m just throwing those numbers out but as an example you’re using a lot more of resistive material in that kind of design, a modular design. But you have these smaller PCBs and essentially you use more material and that’s what you want to do.

Holden: And that’s clearly what Sandborn’s software showed. The more you shrink things down and use the embedded capacitor resistive devices in the sensor or module, the more cost effective it is unless you’re using an additive process. But since most of the materials are subtracted and not additive, the software allows you to choose both additive and subtractive or allow both to be plotted to see the difference. But I agree, the challenge is to take the applications that you’ve all talked about and step back and show the partitioning or the change in

thinking that allows performance to go up and cost to go down by doing things differently than we’ve always done it.

I haven’t seen any articles that talk about the way we did it 20 or 30 years ago, where it’s going to be like this, but if we partition it like you said and put the interposer in there, not only do we save costs but maybe now we don’t have to buy fine pitch devices because the interposer can be 0.5 mm pitch, but the top of the interposer can be 1 mm. Now you’re no longer forced to use very exotic HDI technologies on a whole board when the HDI is only used on the interposers—a big advantage in performance and cost. Nobody’s written an article that says this doesn’t just apply to mobile phones or to earphones, but let’s step back and see how miniaturization can improve things in general or take away problems that are plaguing you now.

Matties: You mentioned the North American market is not really tied to the mobile phone; what impact or advantage or opportunity exists for North Americans with this technology?

Are we missing something, or is there a story to tell here as well?

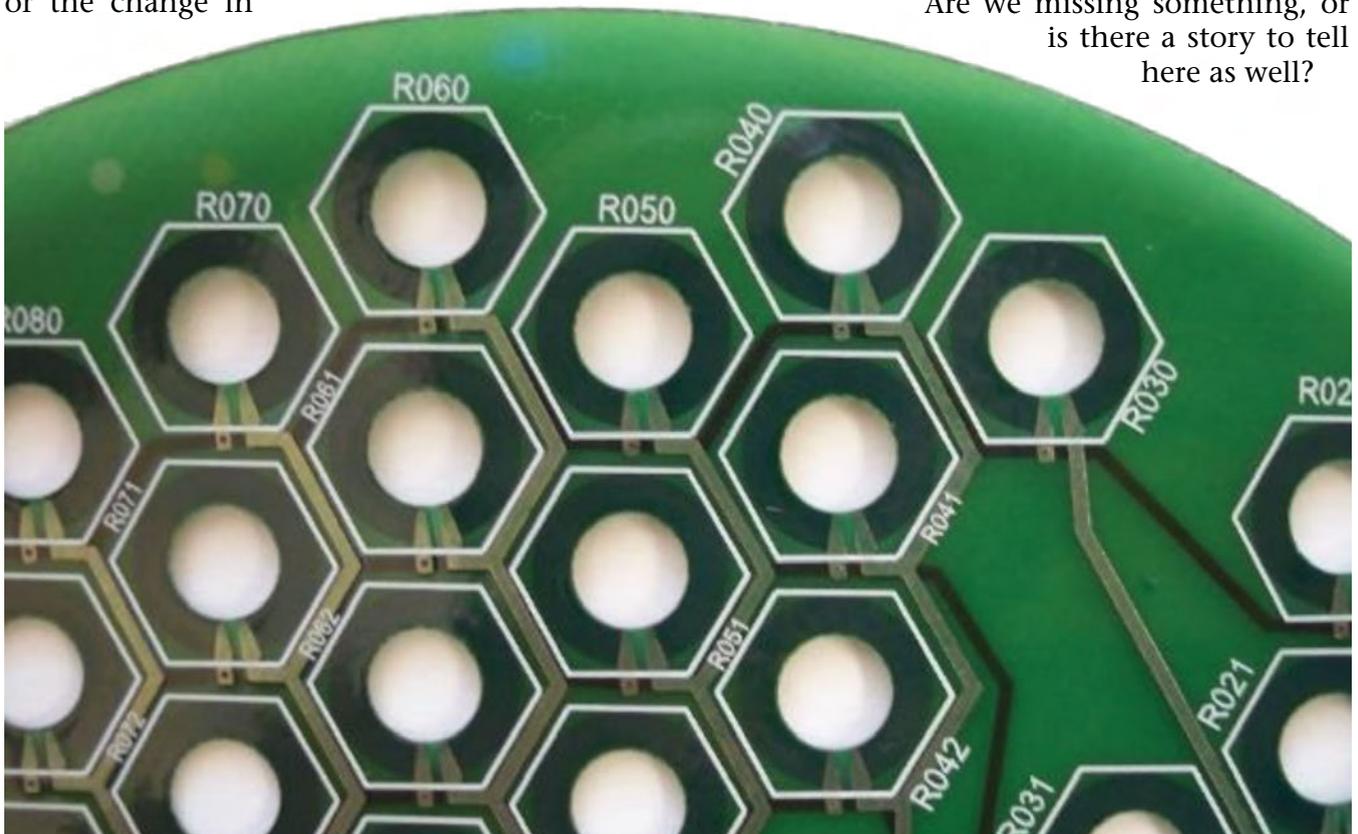


Figure 7: BioMed heater application—soft tissue expansion.

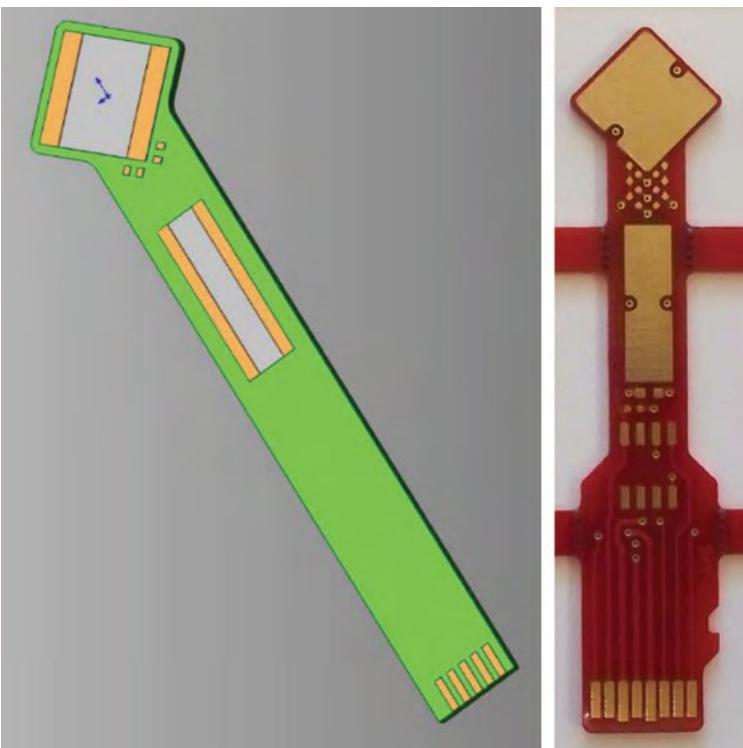


Figure 8: BioMed heater application—fluid delivery.

Herrera: I think a lot of the designs are created in America. Now the actual fabrication and such may be going overseas, but most of the designs are still happening here. The designers here for Qualcomm and that stuff, a lot of the design work is happening here and then it's being sent out to be mass produced and so forth.

Matties: Are there other applications that might be a competitive advantage? Perhaps for someone that says, if I use this in my automobile circuits, for example, I'm going to need functionality, space, etc.

Herrera: That's interesting you bring up the automotive market. In my opinion, the millimeter wave, the radar stuff, the sensors that are going to be going into the cars, again those are modular designs. I think that's a great opportunity there, and the opportunity is performance related. Like Dan was mentioning, you remove the chip component and you're reducing the parasitic inductance involved with the surface mount chip package and the PCB footprint. There are less physical transitions for the signal

to propagate through. And when you're going out to these 66 gigahertz, 70 gigahertz frequencies, a small improvement can make a big difference.

Matties: Is the reliability improved as well?

Herrera: Yes, especially in operating environments exposed to wide spectrum vibration and extreme temperatures that may occur under the hood. Replacing a surface mount component with one embedded in the PCB adds an extra layer of protection. In automobiles, as in aerospace, there will be a lot of redundancy, so that can be an opportunity there, but then who's to say that, as these things are being designed, the manufacturing and the processing won't be sent overseas because it can be done

Goldman: What types of components are embeddable? Is it just capacitors and resistors, or are there more?

Brandler: The one other thing is inductors. There are just three kinds of passives that we usually talk about. We don't call diodes passives, but there are resistors, capacitors and inductors. Inductors are basically little spiral designs, fine-lined things. There may be other chip-type things embedded in the cavities and so forth, but basically when you're talking embedded passives 99.9% of them are going to be either resistors or capacitors. I don't know how many people are making inductors because they don't have to buy anything from us to do that. But the rest of it is some form of active component.

The big challenge with active components is getting reliable interconnects, and they're doing it. I think that's the next big thing to get devices off the surface of the board. I would also like to add that, while we're talking embedded, sometimes we use the word buried meaning within a multilayer structure, an HDI. For these cellphone MEMs modules, a lot of them use surface resistors where the only thing over them is solder mask. Basically, it's like solder mask on bare copper except they're over the resistor element. One of the challenges for the board shops that also drives up the cost is when you're doing a surface resistor or an embedded resistor

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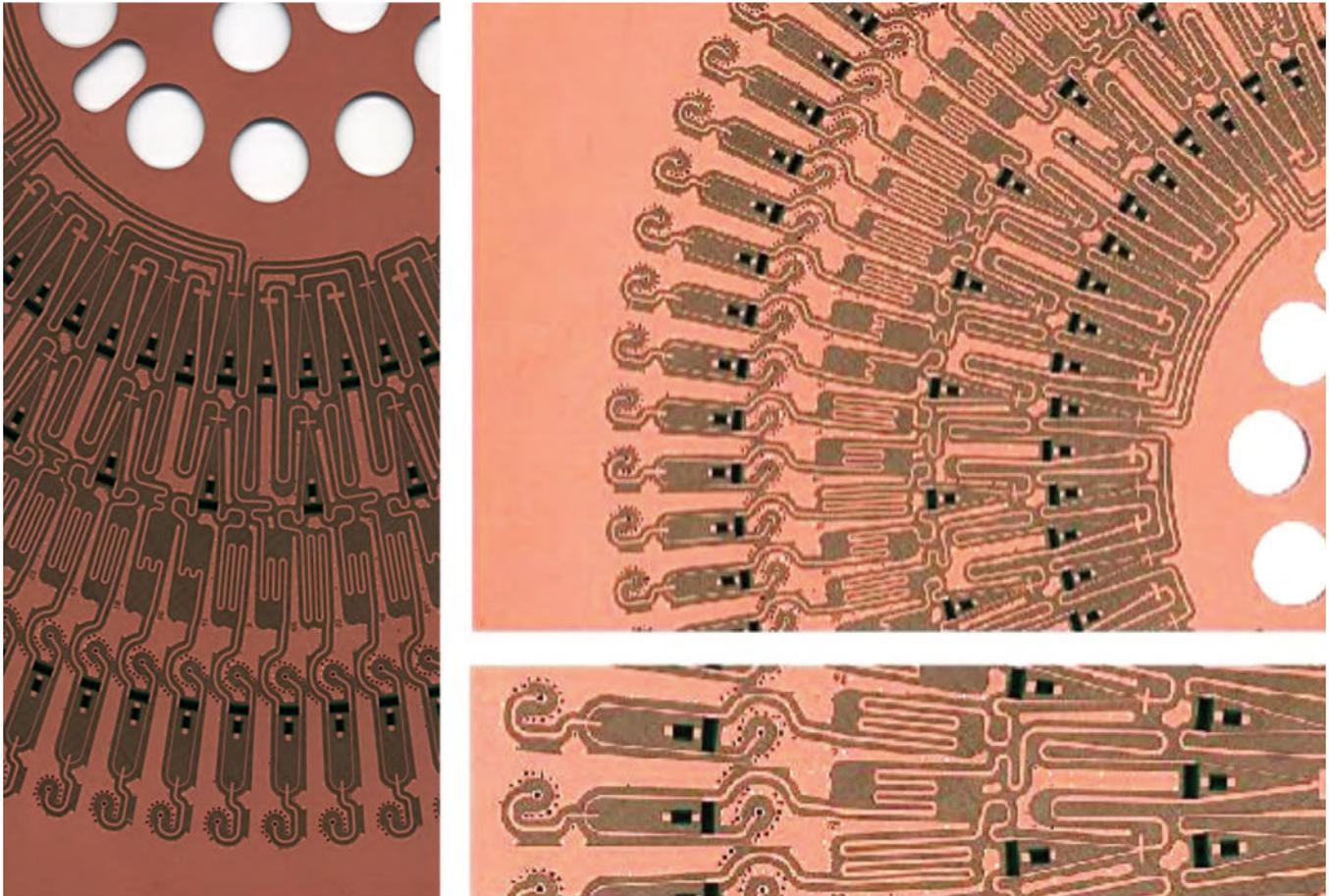


Figure 9: RF power divider application in Globalstar satellite antenna.

on a board that has buried vias. Then you panel plate because you have to metalize the holes, then pattern plate and etch through more copper for the second etch to define the resistor elements. Not only is it difficult, but it adds cost.

Before we thought surface mount resistors are inexpensive and all we're doing is putting solder mask over them; in terms of fine-line etching they can be just as much of a challenge as anything else. But that's old news. The new news is the buried vias and sequential build type PCB constructions where the resistors are in the subassembly of the sequential build and are essentially buried surface resistors; so there isn't solder mask over them, but prepreg or whatever they're using to build it up with.

The challenge, again, is using direct imaging to etch through not only the copper cladding or the OhmegaPly copper, but etch through the plating as well. There may be a 25-micron mini-

mum on the wall of the hole that turns out to be what you're adding to the traces and then etching becomes more difficult. People do it all the time, but you're adding cost to it.

Holden: The Japanese are still working on this. What are the Japanese doing on embedded components? I firmly believe their big focus is miniaturization of everything; they certainly have more examples of miniaturization than we do. Their mobile phones are smaller than ours are, and they always try to make the lightest ones they can get by with or the thinnest ones they can get by with.

Brandler: I agree with you on that 100%. We are working with some Japanese companies that have, since manufacturing is expensive, also offloaded some of theirs to Taiwan or Malaysia. We're working with Japanese companies

who are doing their manufacturing in Malaysia with their automatic lines and so we have to supply rolls instead of sheets, which is our preference—laminated sheets. We also supply rolls for the Japanese companies. There is something going on but they have their own technology and they do exquisite work. There's no question about it. They're top notch.

Stephen Las Marias: I've been hearing the challenges are in the design and the fabrication of the boards with these embedded components, but do you see any relevant challenges when it comes to the PCB assembly side?

Brandler: Normally our thinking is by embedding all components we make assembly easier by limiting solder joints. The only thing I've really heard that seems to be bothering them is in-circuit testing. Because if you're starting to embed actives, now you're doing in-circuit tests on essentially a bare board, and since the board is not fully populated, you often cannot do a complete in-circuit test and so maybe you're just testing for continuity and that all the connections are right. Normally with embedded passive resistors you're not only testing for shorts and opens at the bare board level, you're testing for the value of the resistors. But now with actives, the testing at the bare board level becomes a lot more complicated, because as Happy said, you don't want to get to the point where you've populated the board with all these expensive semiconductors and then find out that some of the embedded ones are no good. That's the only assembly issue that I've heard that they seem to be concerned about.

Herrera: I just want to make one other comment about opportunities for North America. Going back to this whole modular design thing and the idea of deploying sensors, whether they be for industrial applications or even in homes, these low-power energy-harvesting communicating sensors I believe are a great opportunity for North America. I think we'll see that here more so than in other parts of the world, at least I'm hoping. Like the idea of deploying these sensors everywhere and again it goes back to the modular design. I think that's an oppor-

tunity that people here in the States should be looking at if they're not already.

Brandler: Yes, sensors. When we talk about autonomous cars, all these autonomous cars are driven by sensors and loaded with sensors. The question is how many ports are they going to have and how vulnerable they'll be to hacking, and so forth. But tons of sensors, and who's going to build them, I don't know but they're going to require them. You're going to have tires that take control in a skid or something. You know there'll be all kinds of things going on.

Matties: It's definitely a world of sensors and measurements now, isn't it?

Holden: My son's an electrician and I encouraged him to go back to school and become specialized in electronics and other forms of energy because I told him that in a few years, homes and businesses won't use electricians anymore because every switch and every bulb will have a sensor in it. You just mount it and plug it into a local area network and it doesn't require a licensed electrician anymore because it will all be done in the module in terms of what turns on and what turns off, etc. So because of this cost of labor and the cost of an electrician versus the cost of an untrained, unskilled person putting together house wiring, he needs to bolster up and move up in the terms of technology of electricians and to control wiring and specialized things.

Since I came from the automotive electronics in my last job, the cars just have a local area network and every light bulb and turn signal and brake pedal has a sensor on it. There's no longer point-to-point wiring, which is why you can't troubleshoot your cars anymore. Because it's all a redundant pulse signal that makes that left or right turn signal turn on. It's no longer closing a contact on the steering column that makes it turn on, because those modules only cost a nickel because they're purchased by the hundreds of millions. The interesting thing is we didn't have part of it when it was a wiring harness and now somebody has to make all of those modules and assemble them on these big panels, usually done in the Far East. But none-

theless, they've reduced the cost and allow the cars to be a lot smarter. That form of application will slowly pervade everything.

Matties: That will also contribute to, as we continue to see this advance, a lot of different design opportunities for the automobiles as well, because you don't have the standard constraints that you may have had otherwise.

Holden: Yeah, because GenTech just shipped their first set of rear-view mirrors for Cadillac in which the rearview mirror is 100% LCD, because the camera is on the outside, on the top of the car. The challenge was that for safety and automotive sources, if the electrical fails it has to revert to a reflective mirror, and that took a lot of work on glass technology and thin films to make an LCD also revert to being simply reflective. I asked somebody why would you do that and they said the car guys don't like that rear window, and if they can take the rear window away where you don't have to look at it through a mirror then they have the opportunity of a lot more styling and other types of benefits. So two cars now have 100% LCD rear view mirrors; it's no longer reflective.

Matties: That's a great example, and when we do this for the cockpit of airplanes then the nose of an airplane might look a lot different if we don't have to worry about the windows for a pilot to see out of.

Holden: By watching what is being pioneered in the mobile phone and automotive industries, new innovators will apply these sensors as solutions to their problems. Just like I said, we're going to have wearable electronics, but we're not likely to have four-inch by four-inch circuit boards or something like that. They're likely to be very tiny modules in wearables just simply to make them more convenient and to get through a washing machine—although I still believe in printed electronics where they're all disposable, where you only use them for one to five days and throw them away.

Matties: Good, well thank you gentlemen. This has been extremely interesting.

Brandler: Okay, thank you. We appreciate the opportunity. **PCBDESIGN**

Voice-Based Assistant Robots Accounted for Nearly 50% of Global Service Robot Sales in 2016

Rapid progress in the development artificial intelligence has allowed humans to communicate with robots using natural languages. TrendForce's breakdown of global sales of service robots for 2016 reveals that voice-based assistant robots accounted for the majority share of the total sales at nearly 50%. Robot vacuum cleaners made up the second-largest share of total service robot sales at nearly 40%.

"Voiced-based robot assistants have been on the market for many years, but sales have not really taken off until recently, when they include new functions such as remote operation of connected appliances and Internet searches," said Harrison Po, senior manager of TrendForce's photonic and innovative technologies research.

For example, Amazon has become a major vendor in the service robot market with its Echo speaker, which arrived on the market in 2014. Echo achieved

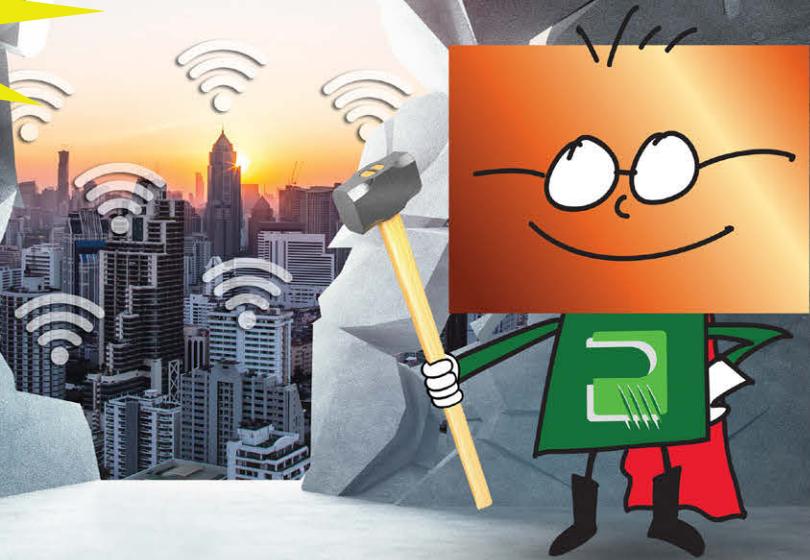
a sales volume of around 5.2 million units for 2016.

Several global brand companies across different industries have entered the service robot market. Well-known examples are Honda's ASIMO, Softbank's Peppers and Amazon's Echo. Sharp, Hitachi, Toyota and LG Electronics are also developing voice-based assistant robots.

A closer look at the development of key technologies behind voice-based assistant robots finds that Amazon not only benefits from strong sales of Echo speakers but also from the adoption of Alexa by other brands selling similar hardware. LG Electronics' Hub Robot, Ubtech's Lynx and Lenovo's Smart Assistant, for instance, are all running on Alexa. On the other hand, even more companies have chosen to build their voice recognition technology for their robots or work with startups such as Fuetrek, which specializes in speech recognition and UI solutions.

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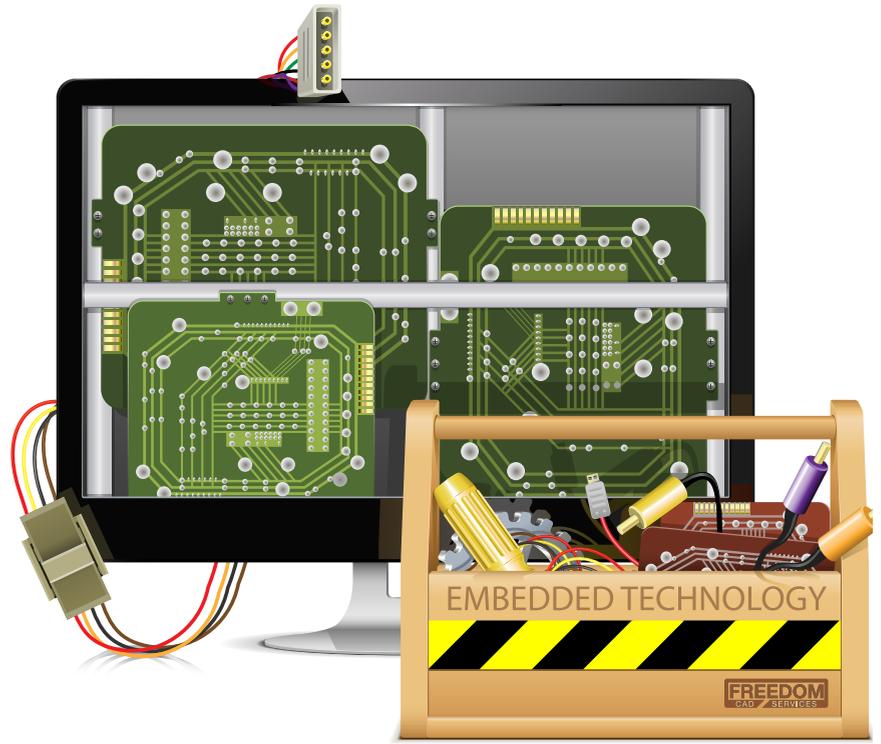
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Embedded Technology: A Useful Tool in Freedom CAD's Toolbox



by Andy Shaughnessy

I-CONNECT007

Freedom CAD has been designing and fabricating boards with embedded technology for years, and doing some innovative work along the way. I asked Scott McCurdy, Freedom CAD's director of sales and marketing, to share some details about their embedded processes, as well as the challenges and opportunities that embedded technology offers.

Andy Shaughnessy: Scott, I know that Freedom CAD has some experience with embedded technology. Tell us a little about that. Do you do a lot of embedded work?

Scott McCurdy: We see increasing use of buried capacitance cores in the designs we do for our customers. This technology has been around for many years, but there are thinner materials available today that use thin film dielectrics instead of woven fabrics. There are many benefits for integrating embedded capacitance lay-

ers into board designs for improving the power delivery network. Our signal integrity engineer believes strongly that embedded capacitors definitely have a place in today's designs where, at frequencies between 10 and 100MHz, a low-inductance energy storage strategy can actually reduce the number of low-value caps needed on a board.

Shaughnessy: That's interesting. And I understand you've done some embedded capacitance designs with FaradFlex material.

McCurdy: Yes, we have several customers who spec this Oak-Mitsui Technologies FaradFlex material especially in high-speed telecom applications. DuPont and 3M make materials for embedded capacitance applications, as well. These thin film type materials have thinner dielectrics than woven fabric which provides additional benefits.

Shaughnessy: Does Freedom CAD do any buried resistor designs?

Engineering And Providing Balanced Interconnect Solutions



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Scott McCurdy

McCurdy: We have very little experience with buried resistors, mostly because our customer base isn't asking for this. However, as product miniaturization continues, I'm certain that industry will have to embrace the use of embedded resistor technologies. It's another method of freeing up surface space and increasing performance and reliability. Some of the CAD design vendors have software tools for designing embedded resistor layers. Ticer Technologies and Ohmega Technologies make great materials for this.

Shaughnessy: You all have done some really cool planar magnetic boards. Can you shed a little light on that? Does this entail literally placing magnets on the board to act as inductors?

McCurdy: We've done some designs where we have routed a spiral of circuits on the inner layers to create the windings of a transformer. We design cut-outs in the board where low profile magnets are placed to bridge over these coils. You end up with a much shorter transformer because it's actually "in the board" rather than solder on top of it. Also, this technology provides improved heat distribution.

Shaughnessy: Do you ever design boards with actual components inside the board?

McCurdy: One project we did last year was designed with a cavity in the board. We put circuitry in the bottom of the cavity where components were placed and soldered on. It was a challenging design solution for this unique application, and was expensive to fabricate and assemble.

Shaughnessy: What do you think are the biggest pros and cons of embedded technology?

McCurdy: There are a lot more positive benefits as board density increases. There are the physical benefits of freeing up surface real estate by embedding the caps and resistors. You can reduce the overall thickness of the boards, which helps your drill aspect ratio. There are improvements in quality and reliability. Embedded passives will also improve the electrical characteristics of the design

with improvements to signal integrity, power delivery and noise resonance. The downside had always been cost, but there has been a huge increase in the usage of embedded passive technology in smartphones, which has tremendously increased the volumes of scale, and that has made the pricing more attractive. The trend to embedded passives will only increase from now on out.

Shaughnessy: Is there anything else you'd like to add?

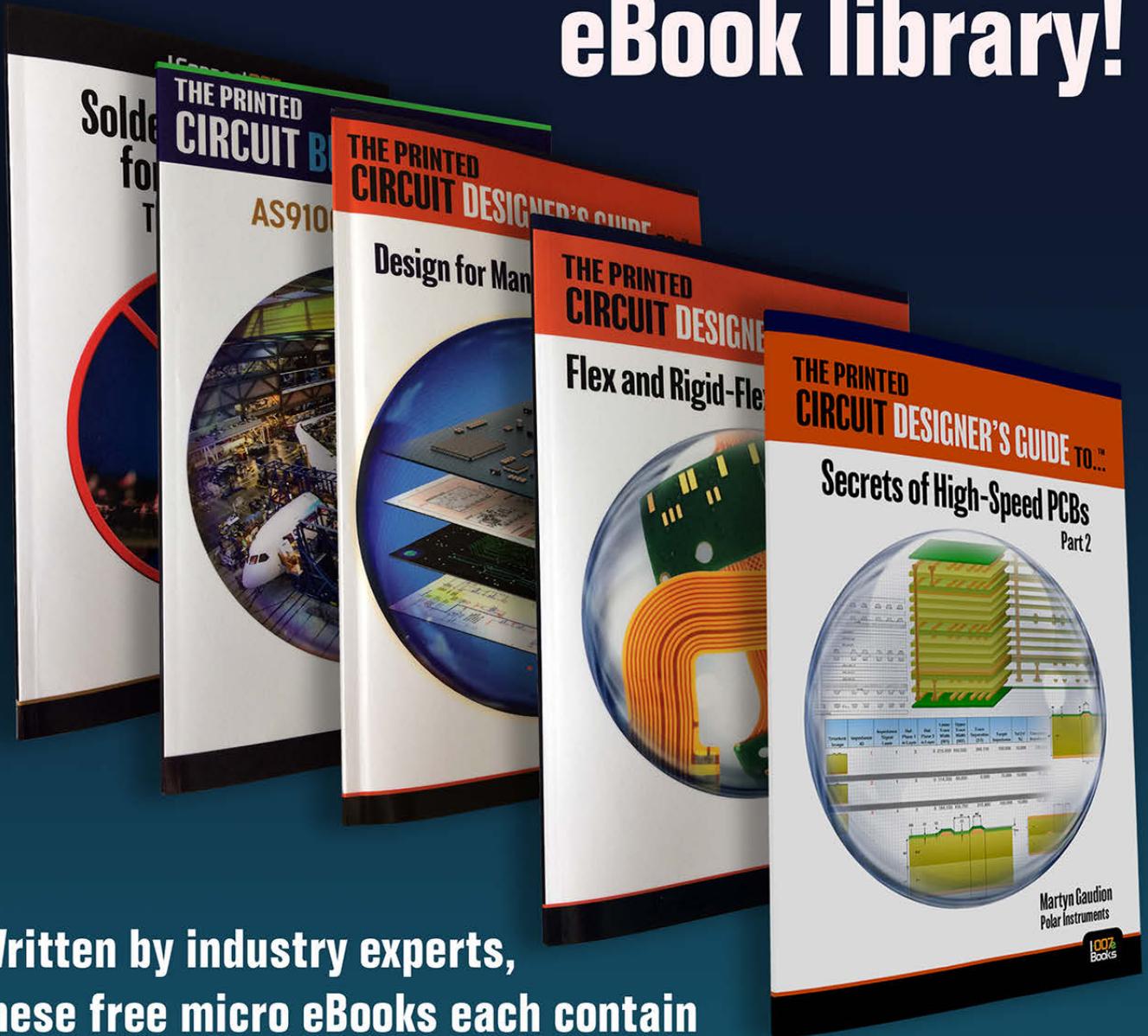
McCurdy: I would suggest that designers and engineers investigate embedded passive solutions. Visit the websites of the companies that make and supply these materials to learn more about it. Contact your board fabricators and have a good discussion with their technical people. Find out what experiences your design house can share with you. The solutions are there and these are the people who can help you take that next step for advancing the technology to improve or make your next product possible. Or you can call me if you have any questions.

Shaughnessy: Thanks for your time, Scott.

McCurdy: Thank you, Andy. **PCBDESIGN**



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Embedding Components, Part 2

by Vern Solberg

Note: [Part 1](#) of this column appeared in the June 2017 issue of The PCB Magazine.

Technology and processes for embedding capacitor and inductor elements rely on several unique methodologies. Regarding providing capacitor functions, IPC-4821 defines two methodologies for forming capacitor elements within the PCB structure: laminate based (copper-dielectric-copper) or planar process and non-laminate process using deposited dielectric materials.

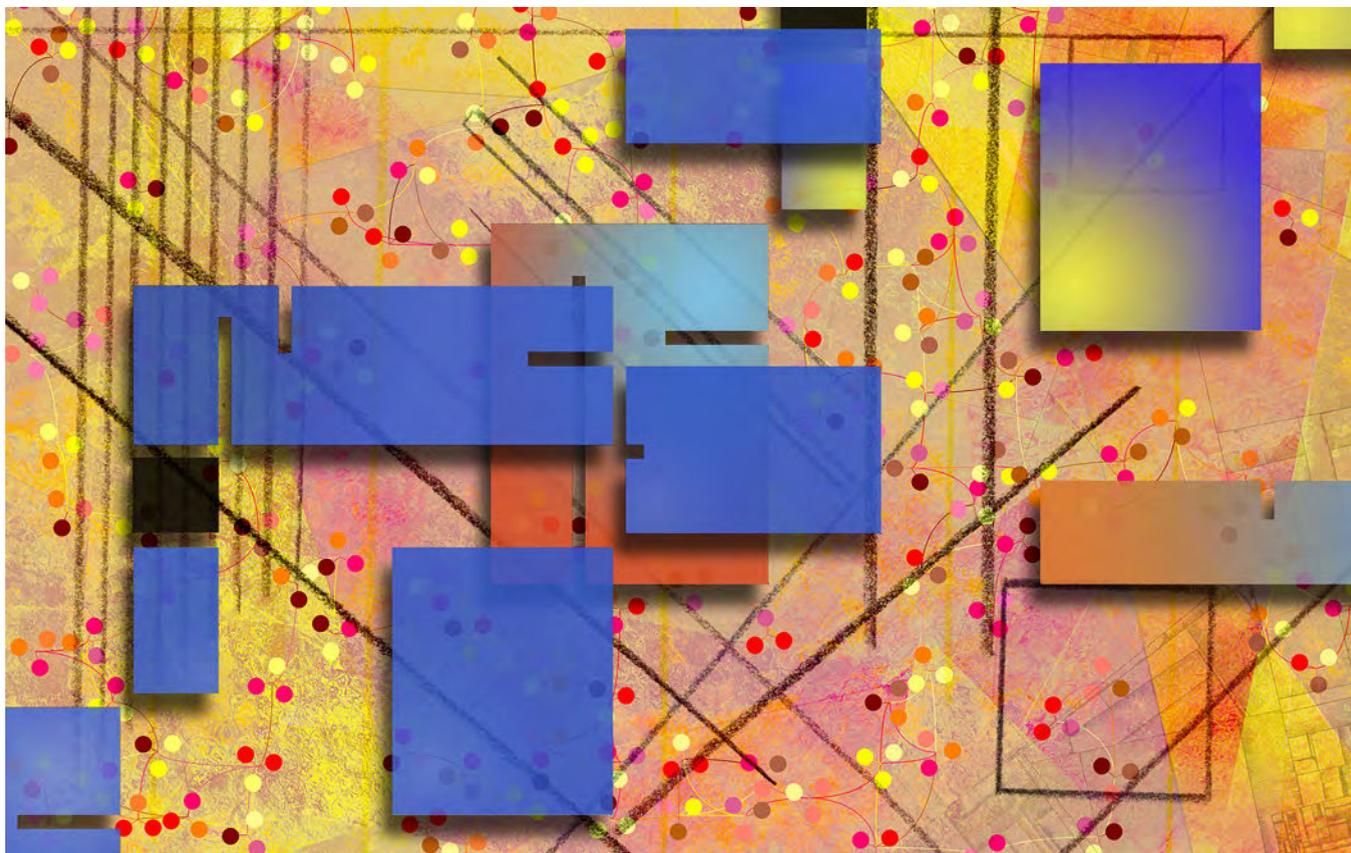
Distributed (planar) Capacitors

Considered the simplest solution and commonly used to replace discrete power supply decoupling capacitors the planar capacitors utilize closely spaced power and ground planes separated by a thin dielectric layer. The dielectric

can be a layer of the glass-reinforced epoxy material, a thin layer of non-reinforced polymer, or a polymer sheet material filled with ceramic powder. This technique will provide significant capacitance and delivers very low inductance. The capacitance range for planar capacitors is 1pF to 1mF, dependent on the dielectric constant, material thickness and area.

Because the planar capacitance is proportional to the dielectric thickness between the power and ground planes, thin dielectrics are preferred. This will increase planar capacitance while reducing planar spreading inductance and minimizes overall board thickness. The reduction of planar spreading inductance also results in a lowering the impedance path while increasing the effectiveness of discrete capacitances.

The total capacitance of the power and ground pair is determined by the effective com-



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mon (overlapping) area of the copper electrodes. This area, times the capacitance density, represents the total capacitance.

The following is the equation recommended for modeling planar capacitance:

$$C = \frac{A \cdot D_k \cdot K}{t}$$

Where:

C = Capacitance (Farads)

A = Area of plates

Dk = Dielectric constant of material between plates

K = Constant

t = Thickness between plates

For example, if the effective area of the capacitor electrodes is 1000 cm² and the capacitance density is 700pF/cm² then the total effective capacitance is 0.7µF. If an additional pair of planes is incorporated in the design, the total capacitance can be 1.4µF. The same logic is used to determine the size of discrete filter capacitors built within the distributed plane.

Polyimide (PI) Film Capacitors

The PI distributed planar capacitors value is calculated by both PI area and thickness. Polyimide film capacitors are typically used to lower the impedance (due to low inductance) of the PCB portion of the power distribution network and the removal of most, if not all, decoupling capacitors of 0.1 µF or lower value.

For example, OAK-MITSUI furnishes the following formula for estimating capacitance of a distributed planar capacitor using their PI film dielectric:

- 12 µm thick material furnishes 140pF/cm²
- 16 µm thick material furnishes 230pF/cm²
- 24 µm thick material furnishes 310pF/cm²

Deposited Dielectric Capacitors

Dielectric materials that are supplied in the form of paste, liquid, powder, or pre-cut vapor deposited sheet material. These materials can be applied within the layer structure of the PCB using a screen-printing, deposition or lamination.

The capacitor dielectric requires two conductor planes using the copper foil of the PCB or other conductive material that are applied over the dielectric element by screen-printing or additive plating. For example, screen-printing techniques are commonly used to apply polymer thick film (PTF) and ceramic-filled polymer (CFP) dielectrics onto an etched copper pattern followed by screen printing of a conductive (silver-filled polymer) material over the dielectric to form the second termination. The capacitance range for the PTF and CFP composites is only 1pF to around 10pF.

Ceramic Thick-Film Dielectric

A variety of capacitor designs may be furnished using the thick-film ceramic (CTF) paste on copper foil process. The dielectric material is applied over a thin pre-conditioned copper foil. The ceramic paste contains ferroelectric Ba/TiO (barium-titanate) powder and a glass powder to facilitate screen-printing. The manufacturer states that one-ounce copper foil is preferred for handling and foil stability during the firing process. In preparation for applying the ceramic coating, a very thin mixture of copper and glass paste is preprinted onto the copper sheet material. The preprint acts as an adhesion promoter for the dielectric layer. The preprint can be applied in a pattern that is slightly larger than the subsequent dielectric layer or it can cover the entirety of the copper foil. Firing of the ceramic material is accomplished in a nitrogen furnace at approximately 900°C. Ceramic dielectric may completely cover the copper foil or it may be ablated to cover only selective areas. The value range for the CTF coated foil is 1pF to around 10nF, dependent on the dielectric constant, material thickness and area.

Ceramic Filled Photo-dielectrics

CFP materials enable creation of a capacitor structure near the outer-layers of the printed board. CFP embedded capacitors developed by Motorola Labs and Vantico AG are also based on barium-titanite composition with a dielectric constant of approximately 20, which limits the capacitance density to a few nF/in². The target of the development was to create a material that would provide a capacitance density of 10

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to 30 pF/mm² and be compatible with standard printed board manufacturing processes.

(Note: Capacitor design guidelines for the printable and foil dielectrics are available from the material manufacturers.)

Formed Inductor Elements

Formed inductors are basically current loops configured to induce a magnetic field for storing and controlling inductive energy. The inductor configuration most commonly designed into a circuit structure is the defined as a 'spiral' inductor. The resulting inductance of the spiral is determined by the length of the conductor in the spiral and number of turns. The spacing between turns is critical as well because the spacing controls the resonant frequency of the inductor. A wider spacing will typically reduce capacitance and raise the inductance frequency. PCB planar spiral inductors can be used as antennae or components for forming high frequency matched filters in a RFID system. The sizing of inductors is dependent on several parameters:

- Line width
- Spacing
- Geometry

Simple inductor elements can be integrated into the PCB circuit path on a single surface of the PCB, but more complex inductor applica-

tions may require a stacked configuration within the multilayer circuit. Single layer copper spirals for example, can only reach about 10nH, however, multilayer spirals can be configured reach up to 30 nH.

Additionally, utilizing a ferromagnetic material either as a core within loops of copper or positioned beneath or sandwiching a spiral in the multilayer PCB can possibly extend the inductor value into the 100nH range.

The resistances and inductances of a formed spiral inductor can be calculated using guidance furnished in IPC-2316. Many software tools for developing the spiral inductor layout are commercially available.

As an alternative to forming component parts, many companies are placing discrete passive components within the substrate layers. In an upcoming issue, "Embedding Components, Part 3" will focus on selecting compatible components for embedding, land pattern criteria and attachment methodology. **PCBDESIGN**



Vern Solberg is an independent technical consultant specializing in surface mount technology and microelectronics design and manufacturing technology. To read past columns or to contact the author, [click here](#).

Artificial Intelligence Imaging Research Makes Diagnosing Disease Easier

A recent advancement in microscope imaging technology at the University of Waterloo could soon make diagnosing disease more accessible and affordable.

The advancement, developed by Waterloo researchers Farnoud Kazemzadeh and Alexander Wong, has led to a new form of spectral light-fusion microscope for capturing lightfield images in full-colour.

The several-hundred-dollar microscope has no lens, and uses artificial intelligence and mathematical models of light to develop 3D images at a large scale. It's a process that currently requires a technician to "stitch" together multiple images from traditional microscope images to get the same effect,

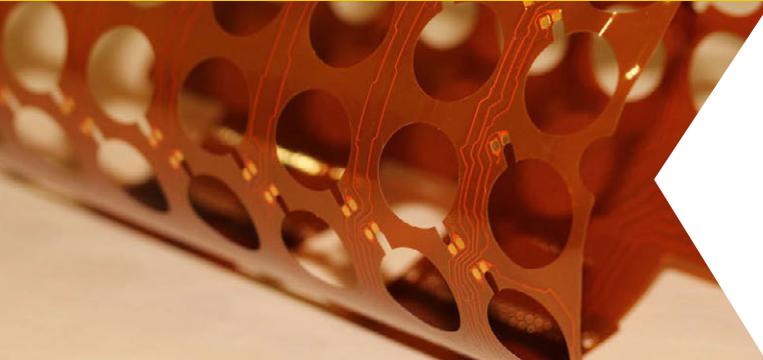
and requires a machine that costs several hundred thousand dollars.

"In medicine, we know that pathology is the gold standard in helping to analyze and diagnose patients, but that standard is difficult to come by in areas that can't afford it," said Wong, an associate professor of Engineering at Waterloo and Canada Research Chair in Medical Imaging.

The current spectral light-fusion microscope represents the second-generation of technology that he patented last year with Kazemzadeh. The microscope captures light fields and allows for 3D images that are approximately 100 times larger than the 2D images captured by more traditional microscopes.

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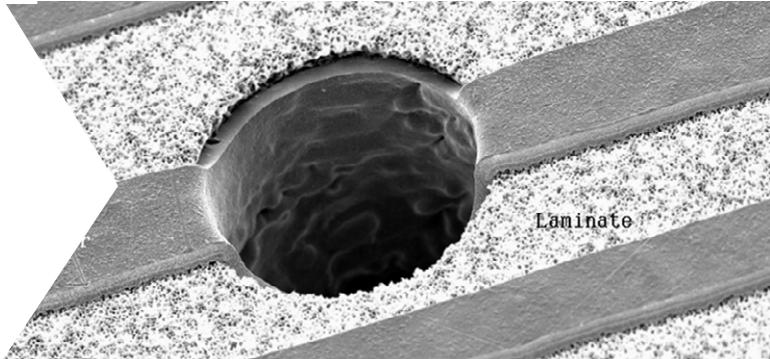
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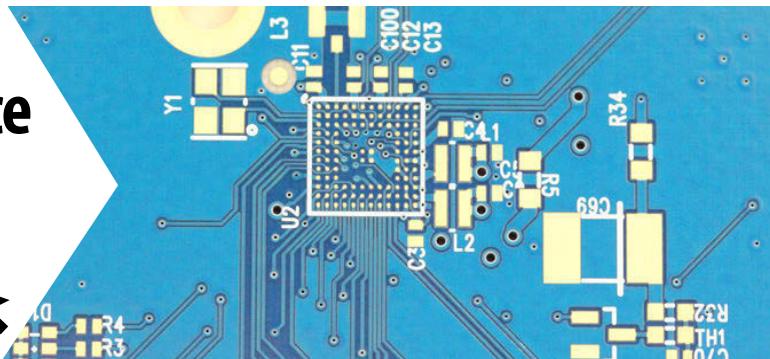
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Performance Evaluation of Thin-Film Embedded Resistors

by **Dora Yang**
PCBCART

Thin-film microstrip circuits have been widely applied in microwave communications, electronic countermeasures (ECM), and aerospace applications, etc. When manufacturing thin-film ICs, it is very important to apply deposited thin-film resistor material to fabricate high-accuracy and highly stable thin-film embedded resistors. Thin-film ICs call for thin-film resistors that meet these stringent requirements:

- a. Square resistance should be wide enough
- b. Temperature coefficient of resistance should be small
- c. Adhesive force with substrate should be strong enough
- d. Thin-film resistors should feature a stable and reliable performance
- e. Filming should be easy and convenient
- f. Should be capable of handling high-temperature processing, high power and relatively wide application range.

A Brief Introduction of Embedded PCBs

The first IC invented by Jack Kilby in 1959 contained only two transistors and a resistor. Nowadays, multiple complex techniques are applied to combine tens of millions of transis-

tors into one single PC chip. With electronic products stepping towards miniaturization and multifunction, a type of embedded passive component technology occurred to meet the increasingly higher demands. The ratio between passive components and active components is approximately 20:1, density has been gradually going up with the ratio rising. With so many passive components embedded in PCBs, the area of an SMT circuit board shrinks by 40% compared to board fabricated through embedded technology.

The early 1980s saw the starting of embedded passive component technology that is usually achieved in a planar form. Based on passive component classification, embedded PCBs can be further classified into embedded resistor PCBs, embedded capacitor PCBs and embedded inductor PCBs. Resistors, capacitors and inductors can be nearly seen in all electronic systems, providing impedance and storing energy for the system. Among those embedded passive components, capacitors and resistors account for the majority, at least 80% of all altogether.

Embedded passive components have been widely applied in filters, attenuators, baluns, Bluetooth applications, power amplifiers, and ore. Furthermore, some trends, including high-speed and high-frequency digital signals, constantly decreasing voltage of passive compo-

nents, gradual strengthening of functions and gradual densification of signal transmissions call for participation of more low-capacitance bypass capacitors to eliminate electromagnetic coupling and signal crosstalk. Therefore, embedded capacitor PCB technology has attracted a wide range of attention by the industry.

Merits of Embedded Resistors

Advantages of embedded resistors mainly come in three aspects: electrical performance, PCB design and reliability.

Electrical Advantages

- Helps improve line impedance matching
- Leads to shorter signal paths and decreased series inductance
- Causes reduction of cross talk, noise and EMI

PCB Design Advantages

- Leads to active component density improvement and decreased form factors
- Calls for no requirement of vias, leading routing to improvement
- Results in simplified boards, shrinking size and/or densification

Improved Reliability

It benefits from its improved reliability, which can be summarized into Table 1.

Factors Determining Performance of Thin Film

Up to now, thin-film resistor material covers a wide application range containing chromium material, tantalum material and titanium material. Compared with chromium thin-film resistors, tantalum thin-film resistors feature many excellent performances such as excellent chemical stability and corrosion resistance, high reliability, wide resistance range and high stability, which makes it an ideal thin-film resistor material with a broad application prospect.

Uniformity of resistor thin film refers to the situation in which how resistors fabricated on the substrate change as substrate position changes in vacuum cavity and how resistance modifies as the same substrate moves. The lead-

ITEMS	PARAMETERS
Low RTC	<50PPM
Life testing	100,000 hours; <2% drift at 110°C
Stable over wide frequencies	Tested beyond 40GHz
Solder joints	NONE
Testing stage	Inner layer and bare board

Table 1: Determining performance of thin film.

ing factors driving uniformity of thin film include: relative position between substrate and target material, deposition rate and vacuum degree. Tantalum nitride (TaN) film applicable to thin-film ICs features excellent uniformity both on the same substrate and between substrates from different positions. Moreover, resistance errors between different batches remain low with excellent uniformity.

Currently, two preparation methods are available for TaN film preparation: physical vapor deposition and chemical vapor deposition. Stability and reliability, accuracy and uniformity of electrical resistivity play an important role in TaN film manufacturing. Up to now, resistance is modified mainly through laser or oxidation to ensure the accuracy of resistance. Both methods, however, feature some drawbacks that laser possibly damages resistance graphics with power withstand by resistor film whereas resistance modification through oxidation suffers from a low rate and bad reliability.

This article takes advantage of magnetron reactive sputtering to prepare TaN thin film and studies the influence of technical parameters such as uniform plate position on TaN thin-film uniformity and performance, determining accurate controlled technology of resistance rate. Furthermore, it studies and analyzes deposition scanning rate and effects of flow ratio of N₂ on TaN thin film and performance.

Performance Analysis of Thin Film

Uniformity Analysis

Under the condition of fixed scanning speed of 105cm/min and 10% of nitrogen flow ratio, uniformity is analyzed for TaN thin film. Inner sheet uniformity can be figured out through the following formula:

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$$\text{Inner sheet uniformity} = \frac{[(\text{Square resistance})_{\text{Max}} - (\text{Square resistance})_{\text{Min}}] \times (\text{Square resistance})_{\text{Avg}}}{2}$$

A resistance instrument is applied to measure resistance and each piece of base sheet has to sacrifice 60 points for measurement. Table 2 shows the measurement result.

Table 2 indicates the resistance distribution of TaN thin film on a base sheet whose size is four inches. Accordingly, it can be summarized that a base sheet with No. 2 position features the best uniformity of inner sheet, while a base sheet close to the plate edge or target material edge features relatively bad square resistance variation, and the inner sheet uniformity of target material close to target material edge is the worst. TaN thin films with bad uniformity can have a huge effect on high-accuracy network resistor manufacturing.

To defeat non-uniformity of thin film close to the target material edge, a uniform plate can be installed to adjust deposited thin film because it is capable of selectively covering deposition area to control film uniformity.

Deposition Scanning Speed Analysis

With the acceleration of scanning, square resistance of TaN thin film displays a trend of enlargement with linear improvement. The higher scanning speed is, the shorter the deposition time will be and so will the number of atoms on thin film. Film will be thinner as well. Three thin-film structures are available for processing: island-shaped structures, net-shaped structures, and continuous structures. The properties of thin film are closely related to its structure and elements. When the film is relatively thin, the film comes in a structure of island. With the film becomes thick, the island structure transforms into net structure and continuous structure.

Position	$R_{\square \text{Max}}$ $\Omega \cdot \square^{-1}$	$R_{\square \text{Min}}$ $\Omega \cdot \square^{-1}$	$R_{\square \text{Avg}}$ $\Omega \cdot \square^{-1}$	Uniformity %
1	55.70	53.51	54.86	2.00
2	48.04	47.08	47.66	1.01
3	53.96	51.91	52.78	1.94

Table 2: Sheet resistance of TaN thin film.

When it comes to resistor thin film, however, three types of phase structures are available: conductive, semiconductor, and insulation. In an island structure, conductive phase particles are scattered in thin film like shutter islands that are surrounded by insulation phase. Therefore, the film square resistance is relatively high. The net-shaped structure, however, is actually a conductive network composed by the interconnection between conductive particles. Insulation phases are scattered inside the network with a low square resistance. Continuous structure is a type of continuously thin film composed of accumulating conductive particles densely, containing few insulation elements. As a result, thin-film square resistance is shrinking.

Nitrogen Flow Analysis

With the improvement of nitrogen flow ratio, square resistance of TaN thin film gradually goes up. This law works dramatically especially when nitrogen flow rate increases from 15% to 20%. That's because the increasing of nitrogen partial pressure leads to the increasing of Ta cavities and conductive type of thin film will convert from electronic conduction to cavity conduction. Thus, square resistance will finally rise.

The increasing of nitrogen flow rate leads to gradual reduction of TaN thin film thickness, which is opposite to the change trend of square resistance. Film thickness is closely associated with mean free path of sputtered particles and sputtering rate of target material.

In summary, thin-film embedded resistors feature agreeable uniformity, leading to its successful applications in a wide range of industries. A great number of tests and experiments have been performed to demonstrate the reliability of thin-film embedded resistors. Therefore, it can be expected that thin-film embedded resistors can be highly relied in numerous electronic applications. **PCBDESIGN**



Dora Yang is a technical engineer from PCBCart, a China-based PCB production service provider. Contact the author through Twitter: @dorayang0227.

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[Standard of Excellence: The Advantages of Flex and Rigid-Flex Circuits](#)

Since their introduction, flexible and rigid-flex circuits have been steadily moving from the fringe of electronic interconnection towards its center. Today, flex and rigid-flex circuits are found in countless products from the very simple to the highly complex.

[TTM Shines a Light on Optical Interconnect](#)

Are embedded optics on PCBs set to make a breakthrough in the upcoming years? According to Dr. Craig Davidson, VP of Corporate Technology at TTM, it might be closer than you'd expect. In a recent interview with the I-Connect007 team, Craig outlines TTM's current pursuit of high-volume manufacturing lines able to deliver embedded optical interconnect and other insights.

[Punching Out! Selling a Company—Seeing it as a Triumph, Not a Defeat](#)

Somehow, there is still a stigma that selling a company is a negative for the owner. Many people think that there must be something wrong, otherwise, they would not be selling. However, exiting a business should be looked at as a triumph for the owner, not a defeat.

[Material Choices for High-Speed Flexible Circuits](#)

High-speed flexible circuits materials are now available from many suppliers. In deciding which materials to test or use, remember the tradeoffs the suppliers made in categories we discussed: electrical properties, mechanical/flex properties, and ease of processing. A choice should only be made after considering these options.

[Flex Talk: Squink—Integrating Fabrication and Assembly in One Package](#)

When walking through trade show expos, I tend to be drawn into product demonstrations on the show floor. Recently, at IPC APEX EXPO, I stopped in front of a piece of desktop printing equipment

that was demonstrating with a flexible circuit.

[All About Flex: FAQs for Extended-Length Flexible Circuits](#)

Extended-length flexible circuits are larger than typically offered sizes in the interconnect industry. The length of these oversized circuits can be anywhere from two to 10 feet or longer. A long, continuous flexible circuit can offer design advantages over using normal sized circuits.

[Ding Cheng of BYD Electronic: Embracing the FPC Factory Model of the Future](#)

The topic of the third issue of PCB007 China Magazine is "The Wide World of Flex." Around this theme, we asked one of the leaders of China's FPC industry, Ding Cheng, general manager of the FPC Division of Shenzhen BYD Electronic Parts Company, to share his perspective about trends in flex.

[Weiner's World—April 2017](#)

China's economy accelerated for a second-straight quarter as investment picked up, retail sales rebounded, and factory output accelerated in March. Gross domestic product increased 6.9% in the first quarter from a year earlier, compared with a 6.8% median estimate in a Bloomberg survey.

[All About Flex: Origami Interconnection](#)

Origami is the art of folding paper; it was believed to have originated in Japan, but historical evidence suggests it existed in several parts of the world during the same period. Origami artistry starts with a flat sheet of paper and by making a series of folds and creases, the result is a three-dimensional figure.

[The Right Approach: Finding the Next Generation of 'Board Rats'](#)

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FPGA PCB Design Challenges

by Barry Olney

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Field programmable gate arrays (FPGAs) are now commonplace in the majority of digital designs. These high-speed, high-gate/pin count devices, that once only provided glue logic, are now offering embedded processors, digital signal processors (DSPs), memory blocks and numerous input/output (I/O) pins in one massive ball grid array (BGA) package. Not to mention the considerable number of power supplies that are required to power the device. This added complexity has introduced many PCB layout challenges—apart from the obvious fanout and route of the fine pitch BGA. The reason for this added complexity is that EDA design tools have not kept pace with the growth in FPGAs. Rudimentary PCB layout tools were developed for designing PCBs, containing components with non-programmable pins such as processors and application specific integrated circuits (ASICs), and may not be suitable to FPGA integration.

The primary issue is generating optimal FPGA pin assignments that do not add vias and signal layers to a PCB stackup or increase the time required to integrate the FPGA with the PCB. Engineers generally do not consider FPGA pin assignments that expedite the PCB layout. Hundreds of logical signals need to be mapped to the physical pin-out of the device, and they must also harmonize with the routing requirements whilst maintaining the electrical integrity of the design.

To further frustrate the situation, FPGA I/O assignment is typically in a constant state of flux throughout the design process. Consequently, many PCB designs must be reiterated simply because the board and the FPGA design teams did not have the I/O pin-out synchronized. This has happened to me in the distant past. The board may go through the process of pre-layout simulation, place and route and then a post layout simulation, to verify all the timing is perfect, only to find on testing, the assembly, that the FPGA I/O pin-out is incorrect on the BGA footprint—damn! Meanwhile, days later, I had rerouted, run design rule checks, resimulated the layout and exported the deliverables.

Also, from a PCB layout point of view, crossovers of the connections should be minimized to give the router the best possible chance of completion. No matter how good the routing technology, crossovers will generally require two more vias per connection and hence more signal layers to route. One should consider:

- Reducing the number of vias to minimize signal inductance, thus transmitting and receiving the signal at a higher quality
- Keeping the trace length of signals to a minimum to reduce transmission line losses, thereby improving signal quality

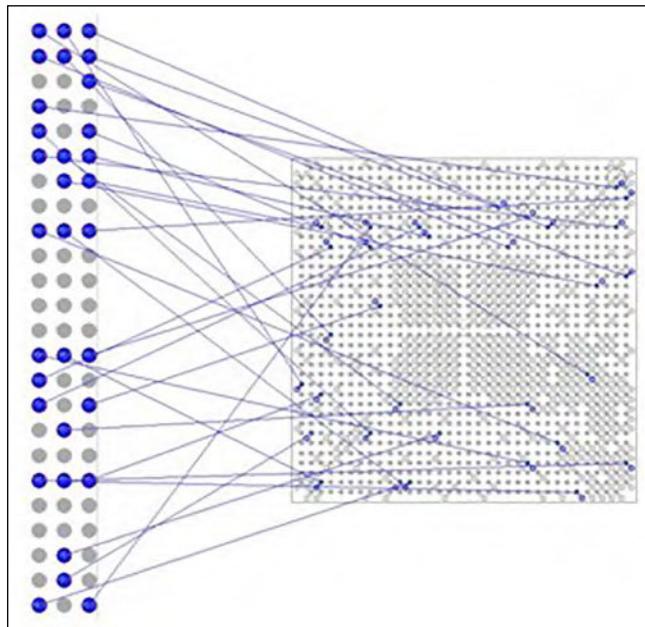


Figure 1: The dispersed connections need to be optimized to eliminate crossovers. (All diagrams courtesy of Mentor Graphics.)

Figure 1 shows the rather disorganized I/O connections of a first pass FPGA pin assignment. This is typically what a PCB designer



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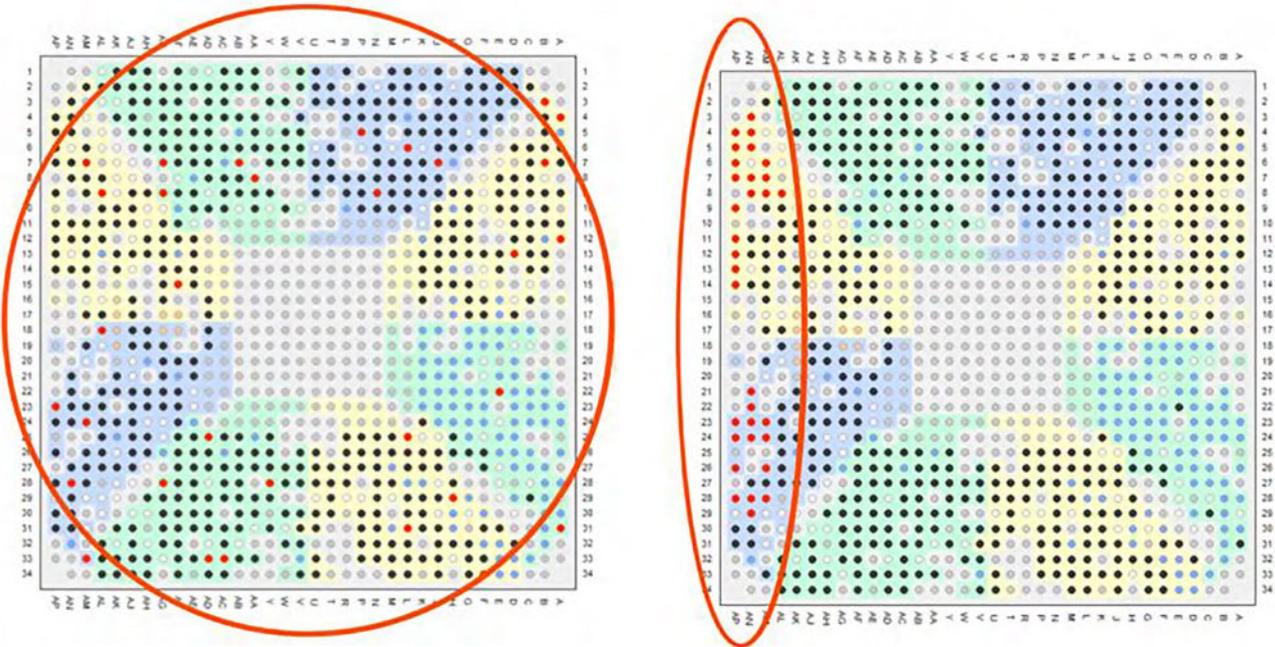


Figure 2: Original pin assignment (left) and modified pin assignment (right). Red is the I/O.

has to deal with, straight from the FPGA place and route tools. To make this more routable, the designer needs to adjust the pin assignment to firstly, be on one outer edge of the BGA. And secondly, order the pins to eliminate crossovers.

The connections in Figure 3 use the modified pin assignments displayed in Figure 2 which eliminates the crossovers making the FPGA I/O signals much easier to route, with fewer vias and fewer layers. This in turn improves the system performance, reduces manufacturing costs and time to market.

The problem now is how to back annotate this modified BGA pin assignment to the FPGA design tools? The manual process is time consuming, tedious and error prone. The key issue is to ensure consistency between the tool sets used in the hardware description language (HDL), FPGA and PCB environments. The language-based HDL representation of the FPGA must be properly represented as a schematic symbol containing the correct pin data, as well as the appropriate mapping to the BGA footprint.

Alternatively, I/O optimization tools can provide parallel paths of FPGA and PCB design, trimming weeks from the design process and

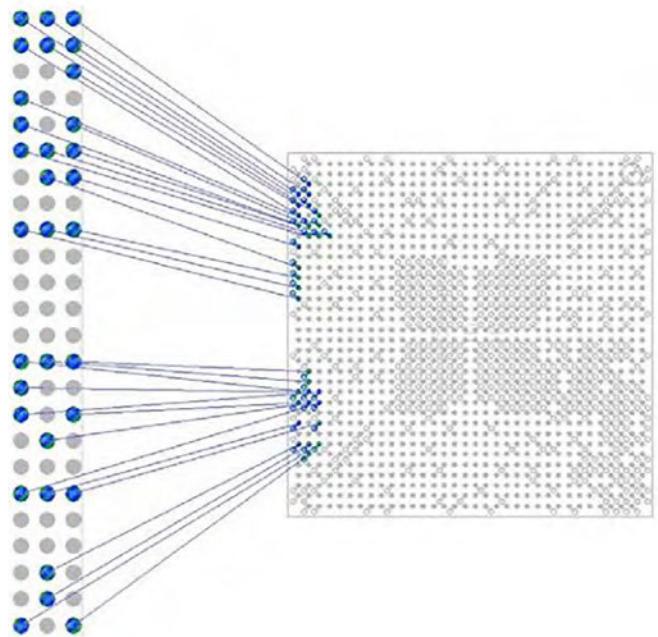


Figure 3: Crossovers are eliminated by modifying the pin assignment.

implementation schedules and providing significant overall cost benefits in the long term. These challenges can be met with such tools as Mentor Graphics' FPGA-PCB optimization

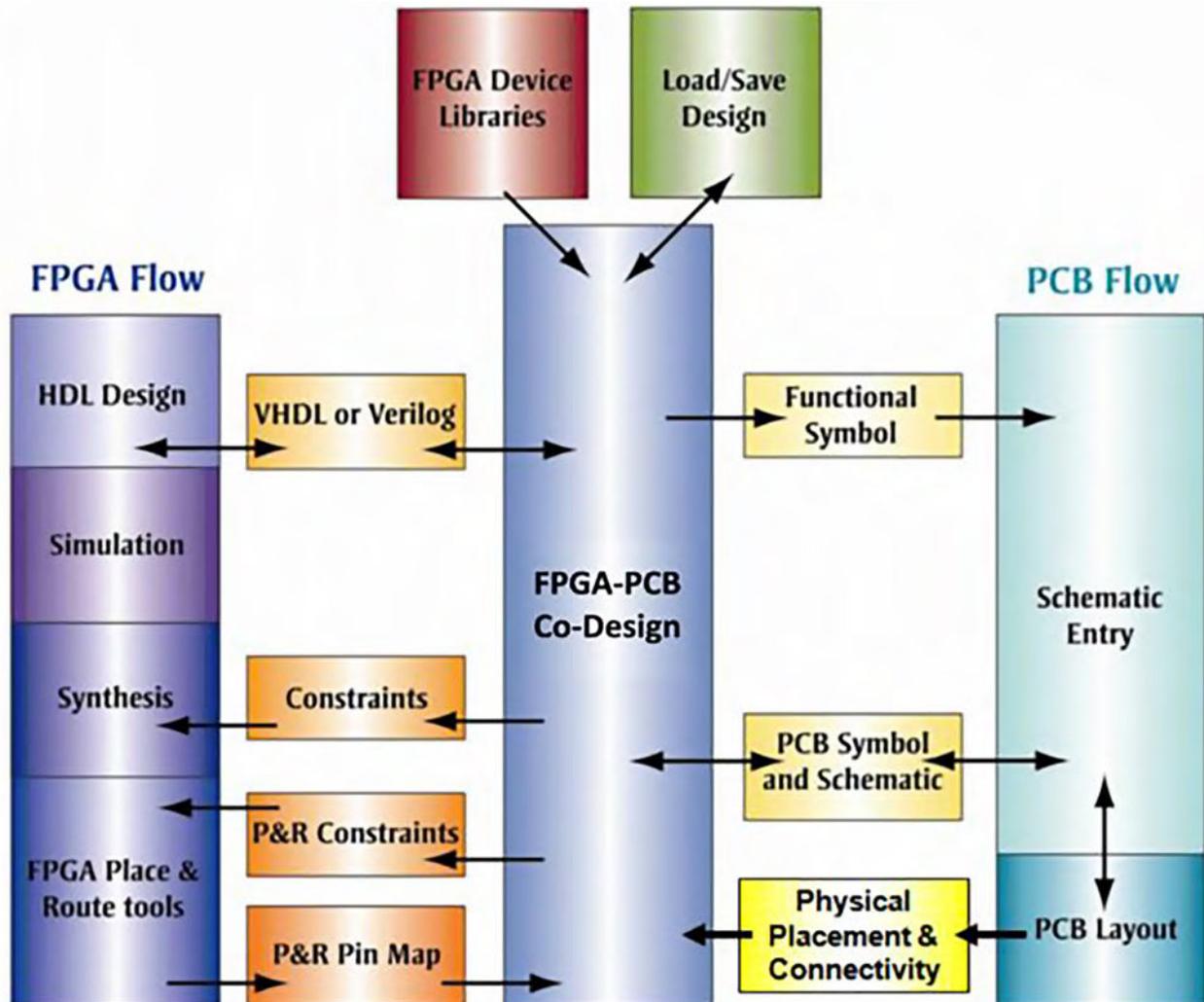


Figure 4: Synchronizing the FPGA and PCB flows.

technology that adds hardware description language (HDL) synthesis and advanced FPGA-PCB I/O optimization to PADS Professional software. This interface, between the HDL design environment and the physical implementation on the PCB, significantly reduces both time to market and manufacturing costs by automating the process, reducing errors and thus iterations.

Figure 4 illustrates the synchronization process. Essentially, once the FPGA design is completed, the pin assignment from the place and route tool is exported to the FPGA-PCB Co-Design software. A schematic symbol is automatically generated, with this pin assignment, and added to the schematic. The completed schematic is then forward annotated to the PCB

layout software. The BGA pin assignments can then be optimized to eliminate cross-overs and then back annotated, via the interface, to the FPGA tools. This synchronizes the FPGA pin assignment to that of the BGA footprint.

I/O optimization needs to be tightly integrated with the PCB design flow and be accessible at any stage of the project. Schematic, PCB layout and FPGA databases should always be synchronized which provides user control of the project's design data flow.

An FPGA vendor-neutral design environment that enables architecture-specific optimization takes advantage of the specific features for each FPGA device to meet the design requirements. Vendor-independent synthesis supports

devices from Altera, Lattice, Microsemi, and Xilinx. Therefore, you may use the same HDL design source files and constraints to target any device and to obtain a synthesized netlist that can be used for place and route with the appropriate vendor tools. This vendor independence, allows users to easily retarget and analyze results for any FPGA device, enabling you to find the best FPGA device to suit the design.

Until recently, the FPGA-PCB I/O optimization tools were expensive and only available with enterprise level flows such as Cadence Allegro and Mentor Xpedition, but are now also an affordable option to the PADS Professional suite of PCB design tools. Automating the error-prone boundary between FPGA and PCB design makes sense. Design teams need to implement new methodologies to ensure they do not negate the cost and time-to-market benefits of using programmable logic in the first place.

Points to remember:

- The added complexity of FPGA integration has introduced many PCB layout challenges.
- EDA design tools have not kept pace with the growth in FPGAs.
- The primary issue is generating optimal FPGA pin assignments that do not add vias and signal layers to a PCB.
- FPGA I/O assignment is in a constant state of flux.
- Cross-overs of the rat’s nest should be minimized to give the router the best possible chance of completion.
- The problem now is how to back annotate this modified FPGA pin assignment to the FPGA design tools.

- The manual process is time consuming, tedious and error prone.
- The key issue is to ensure consistency between the tool sets used in the FPGA and PCB environments.
- Using the right tools can provide parallel paths of FPGA and PCB design, trimming weeks from the design process and implementation schedules.
- Schematic, PCB layout and FPGA databases should always be synchronized which provides user control of the project’s design data flow.
- An FPGA vendor neutral design environment, which enables architecture-specific optimization, takes advantage of the specific features for each FPGA device. **PCBDESIGN**

References

1. Barry Olney’s Beyond Design columns: [Rise of the Independent Engineer](#).
2. “FPGA I/O Features Help Lower Overall PCB Costs,” by Dave Brady, Mentor Graphics.
3. I/O Optimization: Mentor Graphics, PADS literature.
4. FPGA-PCB Co-Design Option for PADS Professional: Mentor Graphics, PADS literature.



Barry Olney is managing director of In-Circuit Design Pty Ltd (iCD), Australia, a PCB design service bureau that specializes in board-level simulation. The company developed the iCD Design Integrity software incorporating the iCD Stackup, PDN and CPW Planner, available for download at www.icd.com.au.

New Technique Enables 3D Printing with Paste of Silicone Particles in Water

In a paper published today in *Advanced Materials*, corresponding author Orlin Velev and colleagues show that, in a water medium, liquid silicone rubber can be used to form bridges between tiny silicone rubber beads to link them together – much as a small amount of water can shape sand particles into sandcastles.

“There is great interest in 3D printing of silicone rubber, or PDMS, which has a number of useful properties,” said Velev, INVISTA Professor of Chemical and Biomolecular Engineering at NC State. “The challenge is that you generally need to rapidly heat the material or use special chemistry to cure it, which can be technically complex.”

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—David Dibble



When Comparing Data Sheets, the Devil is in the Details

by **John Coonrod**
ROGERS CORPORATION



Many PCB fabricators and designers will often compare the properties listed on material data sheets to assist with the material selection process. Of course, this is a wise thing to do when choosing materials, however data sheets need to be reviewed carefully. Comparing information between data sheets may be misleading since there are many variables that go into collecting the data.

One major issue with understanding the information on data sheets and making appropriate comparisons is the test method category. It is possible to test the same piece of material for dielectric constant (Dk) using two different test methods, and arrive at two different—but correct—answers. Most PCB materials are anisotropic, which means the Dk is not the same on the x-, y- and z-axis, where the z-axis is the thickness of the material. Some test methods will test

only the z-axis and other test methods will test the x-y plane. So it is possible to test the same piece of material, using a test method that evaluates the z-axis of the material for Dk, and get a different answer when testing that same material using a procedure that tests the x-y plane of the material. Both answers could be correct, but this can cause confusion when comparing data sheets. It is very important to ensure the test methods are the same when comparing similar materials.

Electrical properties can be misleading since the Dk and dissipation factor (Df) of all circuit materials is frequency-dependent. These properties will naturally change with a change in frequency. Again, when comparing data sheets from similar materials and ensuring the test methods are the same, the subtle fact that the test frequency is different can alter the com-





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parison. All materials will have a lower (better) Df at lower frequencies, and if a comparison is done with material A at 2.5 GHz and material B was tested at 10 GHz, then it is not an equal comparison because the lower-frequency test will naturally have a lower Df when compared to testing that same material at a higher frequency.

Peel strength or bond strength is another property that is often misunderstood. In my years with flex circuit engineering, I found it interesting that the material of choice for one of the most demanding flex circuit applications had very low bond strength. The read-write flex circuit inside a traditional mechanical hard

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“ In my years with flex circuit engineering, I found it interesting that the material of choice for one of the most demanding flex circuit applications had very low bond strength. ”

.....

disk drive had to survive hundreds of millions of flex cycles, yet the material of choice had a bond strength of typically about 1.5 pli (pounds per linear inch). That is considered very poor for bond strength, yet the circuit had excellent long-term performance inside hard disk drives (HDDs). That is because when the circuit is designed correctly and the application is optimized, many times bond strength is not critical. Bond strength becomes more critical when the circuit has mechanical and/or thermal stresses applied. In the case of thermal stresses or thermal cycling, bond strength may not be a major concern if the material has well matched CTE to copper and the other substrates that make up the circuit.

Another interesting point about bond strength is that the value is dependent on specific mechanical properties at the breakpoint

where the copper is being peeled away from the substrate during the peel strength testing. The same material which had poor bond strength and was used in HDD, would have very good bond strength numbers if it was undercured. Of course, there are other properties, like surviving solder float, which would be negatively affected but an under-cured adhesive system will often have higher peel strength during bond testing. The reason is the undercured adhesive is more elastic and stretches at the breakpoint during the peel strength testing. Basically, there is more material hanging on at the breakpoint between the copper and substrate during peel strength testing, and that causes the bond values to increase. The undercured adhesive should not be used in applications, but if a person were to look at bond values only, it could be deceiving. This same thought process should be used when comparing materials that have different formulations.

As a general statement, thermoplastic materials are soft and stretchy, which causes them to report a higher bond strength number than many thermoset materials which are rigid and have a clean breakpoint during bond testing. The bottom line summary for bond strength is that a material with high bond strength is not necessarily better than a material with low bond strength. Bond strength should only be one aspect of material selection and if the material has good CTE and the application does not stress the bond-line of the copper-substrate interface, bond strength may not be a major consideration.

Moisture absorption is another property where the results are often confused on the data sheets. There are many ways to test materials for moisture absorption. One method, which is probably a worst-case scenario, is etching all the copper off the laminate, weighing the substrate, submerging it in hot water (50°C) for 48 hours, weighing it again and the weight difference gives the percentage of moisture absorbed. Obviously, most PCBs are not submerged in water, therefore, comparisons using this test method should be thought of as a reference between materials only. Since there are many test methods for moisture absorption, data sheet comparisons may be confusing if one data sheet

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is reporting moisture absorption from 24-hour testing, at 25°C at 85% RH and the other data sheet is using the 48 hr./50°C/water submersion test method. These comparisons should not be done since the two testing conditions are not the same.

Some test methods for thermal conductivity will test the raw substrate only and other test methods will include the copper of the laminate with the substrate testing. Since copper has a thermal conductivity of about 400 W/m/K, the added influence of copper will certainly improve the thermal conductivity values for a test method which includes that metal. And if the test method includes copper, the substrate thickness during testing is important since a thinner sample will be more dominated by the copper influence.

I have pointed out a few things to consider when comparing data sheets, but there are many more. Just about every property on the data sheet has its own story. To do a fair comparison between data sheet properties, one must consider how they are tested, conditions and the details must be well understood. It is highly recommended that you consult your material suppliers when reviewing information given on any data sheet. **PCBDESIGN**



John Coonrod is technical marketing manager for Rogers Corporation. To contact him or read past columns, [click here](#).

Microelectronics R&D Intensifies to Address High Customer Demand

Governments and industry stakeholders are keenly following developments in the microelectronics industry, as these technologies could potentially disrupt and bolster the Internet of Things (IoT) megatrend. Microelectronics will support eco-friendliness, Innovating to Zero, smart and connected homes, cloud computing and miniaturization trends, and influence the technological progress of a wide range of industries. This will open up opportunities across value chains, and key industry participants are actively entering this technology space to gain an early mover advantage.

“One of the major selling points of microelectronics is its low power consumption. Industries recognize that the technology’s rapid charging, smart antenna, wireless charging, and organic light-emitting diodes (OLEDs) make it extremely cost effective in the long term,” noted Frost & Sullivan TechVision Research Analyst Brinda Manivannan.

Top Technologies in Microelectronics, 2017 is part of Frost & Sullivan’s TechVision (Microelectronics) Growth Partnership Service programme. The study assesses the impact of the top



emerging microelectronics technologies, the innovation strength of each region, and the global market potential of the technology. It also covers the dynamic technologies that enable the convergence of megatrends such as smart cities, vehicle to X (V2X) systems, IoT, and connected systems.

While the benefits of microelectronics are manifold, scientists and adopters are still challenged by the huge cost of research and development (R&D), capital-intensive manufacturing, scalability limitations, volume production and lack of a structured supply chain. However, technology developers are gradually addressing these roadblocks to adoption, with North America leading in technology advancements and Asia-Pacific in technology adoption.

“Microelectronics R&D will also get a boost with the impending bandwidth crunch due to the increased penetration of augmented reality and virtual reality devices. Microelectronics can be

employed to develop faster data transmission technologies such as visible light communication (VLC) and advanced data storage techniques to power data-intensive applications,” noted Manivannan.



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Innovating in the Technology of Stretchable PCBs

Express Circuits, a long-established PCB fabricator in Coleshill, near Birmingham in the Midlands of England, with the benefit of associate companies focused on design and assembly, is recognised for its exemplary customer service and technical support and innovative manufacturing solutions.

American Standard Circuits Completes Asset Acquisition of Camtech Technologies

The acquisition brings increased offshore capabilities to American Standard Circuits and demonstrates American Standard's continued commitment to helping clients with their most pressing business challenges, from prototype to high-volume production.

If It's My Data, I Can Do What I Want, Right?

In the light of the new IoT philosophies that are rapidly becoming the expectation, the problem of flexibility versus risk is resolved on the lower level, as IoT establishes the transfer and availability of data everywhere without the need for "hacking" into internal system database structures.

Global Smart Manufacturing Market: Players Need to Explore New Markets

The global market for smart manufacturing is characterized by the presence of numerous companies, making the landscape fragmented and highly competitive. The competition is being dictated by the demand for huge investments in infrastructure and development of technologies.

Blackfox Program Trains Vets for Manufacturing Jobs

It's harder than ever for managers in the PCB manufacturing industry to find qualified staff, with some reporting that positions are remaining open for months at a time. On the other hand, there are thousands of soldiers, sailors, airmen and marines transitioning out of the service each year and seeking good jobs.

Europe Ramps up Defense Spending as Budgets Rise on Heightened Threats

Defense budgets across Europe will grow by 1.6% on average annually for the next five years, to reach \$245 billion in total by 2021, according to new analysis released today by IHS Markit.

Mentor FloTHERM XT Release Simulates Complex Geometries Quickly, Accurately

Mentor, a Siemens business, has launched the newest release of the FloTHERM® XT electronics cooling software product with advanced thermal management capabilities. The award-winning FloTHERM XT product is the industry's first integrated mechanical design automation (MDA) and electronic design automation (EDA) electronics cooling solution.

Bruce Mahler Discusses Ohmega's Resistive Material Technology

Bruce Mahler, vice president of Ohmega Technologies, sat down for an interview at DesignCon 2017. He discussed the company's latest embedded resistive materials, as well as some of the drivers and challenges in that segment of the materials industry.

Executive Agent for PCB and Electronic Interconnect Technology PrCB Trust Accreditation

The DoD mandate for trust in the PrCB supply chain is mirrored in DoDI 5200.44, which states: "Employ protections that manage risk in the supply chain for components or subcomponent products and services (e.g., integrated circuits, FPGAs, PrCBs) when they are identifiable (to the supplier) as having a DoD end-use."

Developments in the Defense and Protection Markets

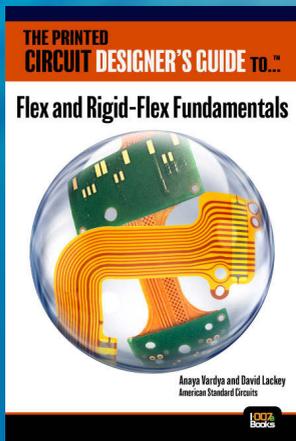
Markets and Markets reports the active protection system market is projected to grow from \$2.84 billion in 2016 to \$4.15 billion by 2022, at a CAGR of 6.50% during the forecast period. Several influencing factors are expected to drive this market during the forecast period.

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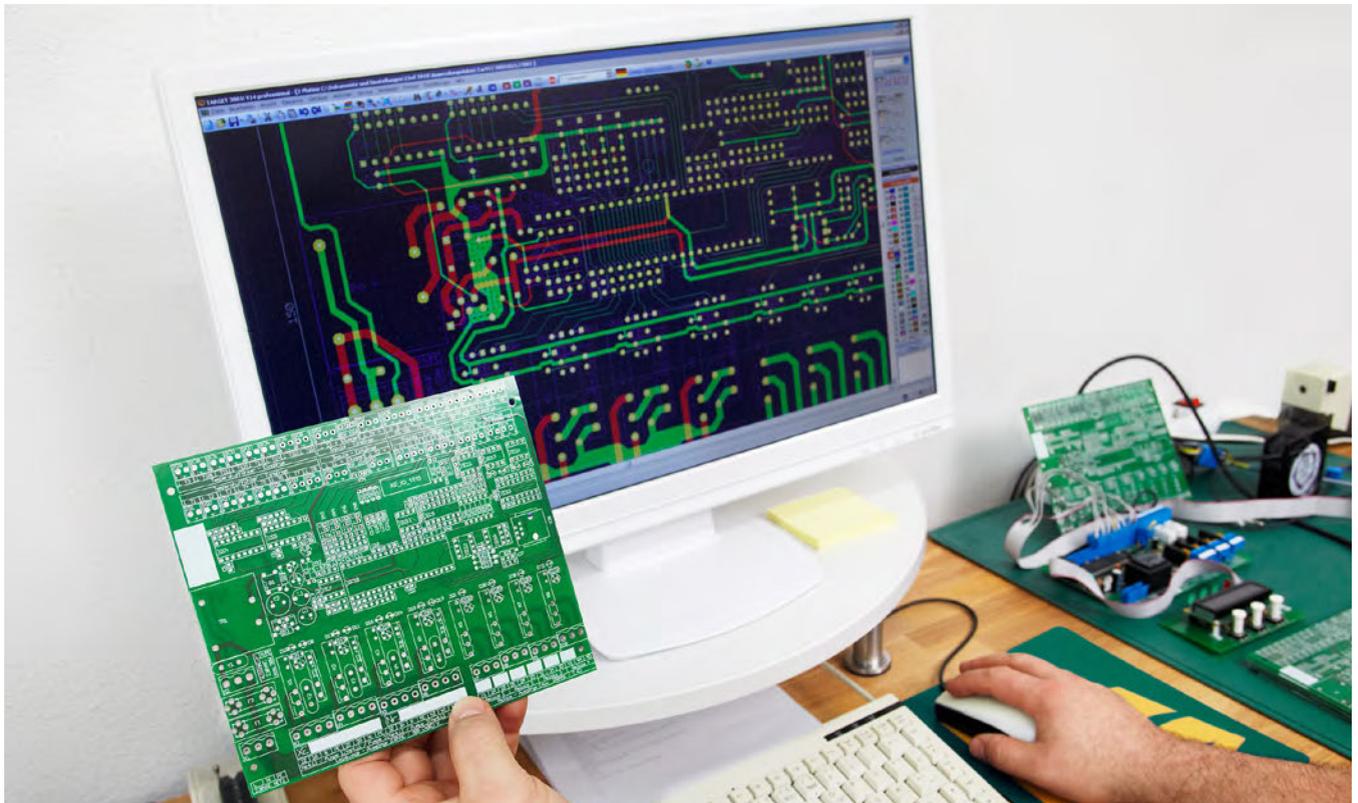
To define and subsequently fabricate a flexible circuit, a set of electronic documents known as CAD files must be created. These files contain all the data needed for each software-controlled machine to perform its required process step. The type of data a circuit supplier receives from a customer can vary widely. In some cases, the files contain a complete set of data to manufacture a one-up part. In other cases the customer may only provide a print or net list and request the fabrication house to provide a quotation for the design layout by creating the data needed to define the part number. In most of these cases, a CAD file is created and sent to the customer for review and approval.

CAD engineers take a CAD file that defines a single part and panelize the data by creating a nested pattern repeated across the panel. Reverse nesting and off-angle part placement may

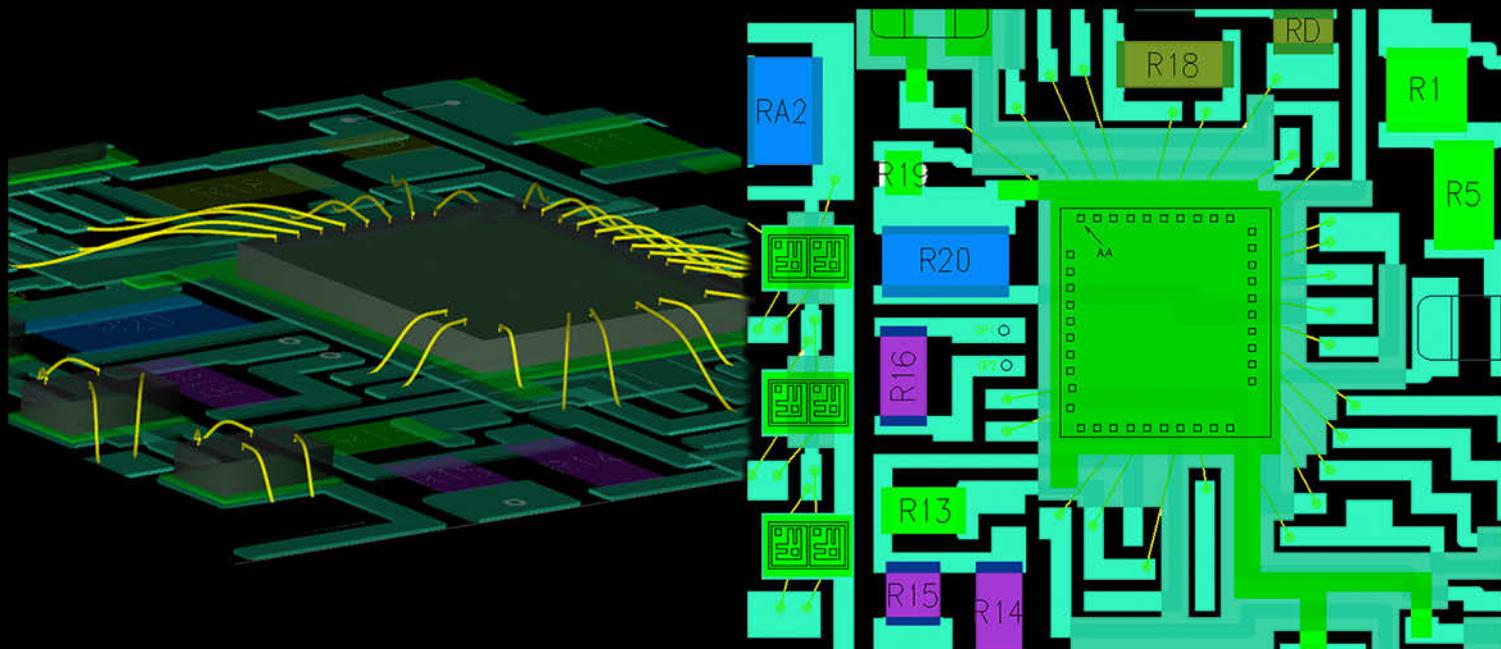
optimize material utilization, which is a constant cost concern. But this optimization needs to be balanced by ease of stiffener placement and component assembly.

Part of the panelization process considers how to best apply manufacturing tolerance corrections such as artwork scaling as a compensation for material dimensional changes resulting from etching, copper plating and coverlay lamination. Material thickness, percent etched and material types all contribute to determining final dimensions. These interactions combine to make initial estimates more art than science. Refinements occur as empirical data is gathered on individual part numbers.

The CAD data is used to create all the electronic files needed for the programmable equipment that fabricates the part as well as the physical tooling. A few examples include:



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- Data is used to define the photo tools, which can be a plastic film or glass, or in the case of LDI (laser defined imaging) the data needed for machine programming. In addition to defining the traces, files contain coupon images, fiducial marks for optical alignment, etched nomenclature and panel serialization codes.

- Vias, through-holes, and registration holes are defined as drill files. The first step, after issuing the material to the manufacturing floor for fabrication, is to drill and rout these holes. Subsequent steps such as imaging or coverlay placement must be aligned to these holes.

- Coverlay: The coverlay layers are often created by drill and routing steps or with laser cutting. The NC drill equipment needs data to define the location, shape and size of each coverlay opening.

- Electrical test files: Electrical testing can be done with a bed of nails tester or a flying probe tester. In either case, CAD data is used to define the test programs.

- Cutline routing: The cutline can be created by NC routing, laser cutting, or a physical die. CAD data is used to create the files for programming equipment that directly creates the cutline or creates the die.

- Nomenclature printing: CAD files are used to define the text that gets printed on the panel. Some of the nomenclature can include:

- Cavity location information on each part in the panel
- Part number specific nomenclature
- Cavity ID
- Any needed orientation or registration markings
- Solder stencils for SMT component assembly
- Stiffeners: The polyimide and/or FR-4 stiffeners are often drilled and routed to a specific configuration
 - AOI (automated optical inspection): CAD files are again used to create the AOI program for machine inspection

Once the complete set of CAD file layers are created, they are run through a series of automated design rule and configuration checks to ensure all layers match up and fit together properly. In addition, the preliminary manufacturing files are reviewed by engineering as part of a design review process. All told, CAD/CAM technology helps streamline and fool-proof the design, layout and panelization of a flexible circuit. **PCBDESIGN**



Dave Becker is vice president of sales and marketing at All Flex Flexible Circuits LLC.

Drones with Just Pen, Paper and a Circuit

Circuit Scribe announced the release of their revolutionary DIY electronic kits, made with just printer paper, a Circuit Scribe pen, and a circuit. A progression from education use to application, the paper kits are currently available exclusively on their Kickstarter campaign.

Creators can draw anything with a non-toxic, highly conductive, silver and water based ink. This low-cost, high-quality electronics kit allows kids and adults alike to express their personality through their own unique creations.

The Original Circuit Scribe product was the widely popular,

crushing their \$85,000 crowdfunding goal and raising a staggering \$675,000 from over 12,000 backers.

The most popular of the DIY kits is the electronic drone. This kit literally flies off the page. Parents working together with their children can create a 4-propeller drone using cardboard and

the Circuit Scribe conductive ink pen. The DIY drone kit will include perforated sections that ensure symmetrical shapes. The shapes can be configured and reconfigured in multiple variations to change the drone's size. [Learn more.](#)



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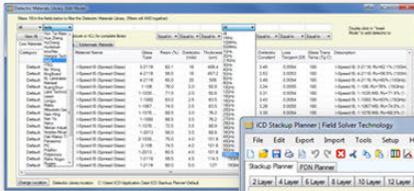
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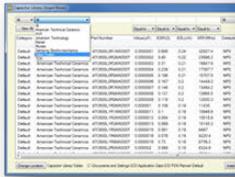
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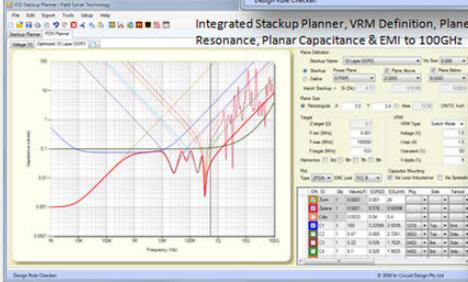
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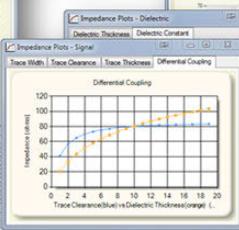


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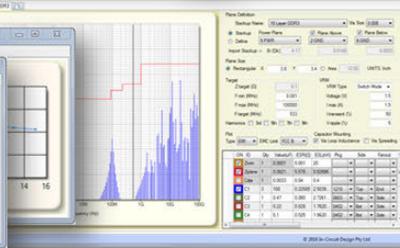
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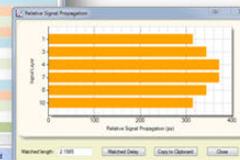


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- Barry Olney



Resins Past, Present and Future

by **Alistair Little**

ELECTROLUBE

I have been working with polymers and resins for more than 20 years now. Modesty aside, I have been involved in several significant developments ranging from structural composite resin and pre-preg systems for the aerospace and automotive industries, to my current activities with a strong team of chemists, formulating new resins for the protection of modern electrical and electronic assemblies.

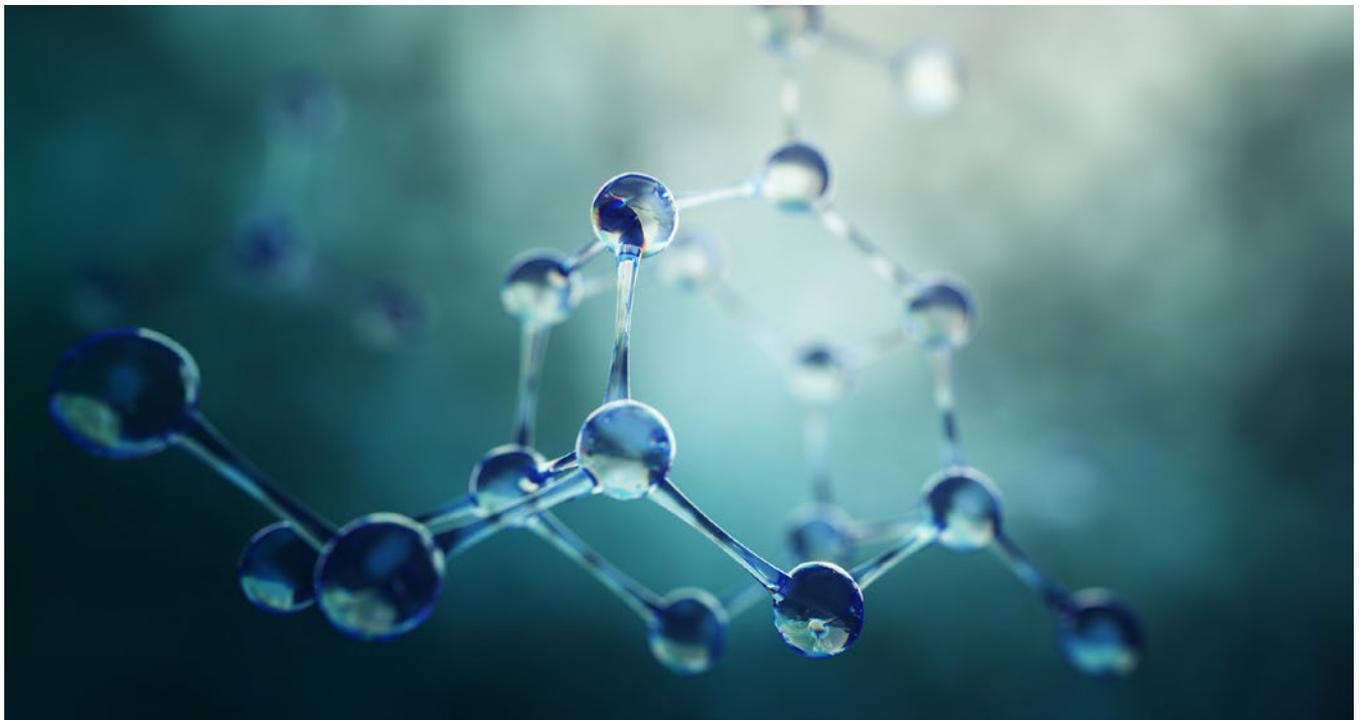
Over this period, the electronics industry has witnessed an extraordinary rate of technological change, and we chemists have been hard at work keeping abreast of developments to ensure that we can supply the materials necessary to maximise the performance of high-performance electronic systems in physically and environmentally challenging conditions.

I thought you might be interested in the progress my industry has made over these past 20 years and how resin chemistry has evolved to keep pace with the remarkable achievements of the electronics industry, such as device minia-

turisation, smart mobile telephony, electric vehicles, and flexible display technology.

Miniaturisation is a great place to begin, because this has posed some of the greatest challenges to developers of resin systems for electronic device manufacturers. As electronics real estate has gotten vanishingly smaller, the density of components has increased substantially and the work these components have to perform, confined as they are, has resulted in a concentration of electrical energy and an inevitable rise in operating temperatures. You only have to compare the size and processing power of mobile phones manufactured in the 1990s with what we have today to see what I mean!

The thermal performance of resins has, therefore, come under greater scrutiny in recent years, and their ability to conduct heat efficiently from electronic assemblies is one of several important considerations when choosing an appropriate resin system. The thermal conductivity of modern epoxy or polyurethane potting



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and encapsulation resins is improved by the introduction of fillers, either metallic or ceramic, depending on whether the resin is desired to be electrically conducting or insulating. The clever bit is getting the packing density right to achieve the improvement in thermal conductivity.

Unfilled resins have a low thermal conductivity, about 0.2W/m.K; we've managed to raise this to 1.54 W/m.K with our epoxy-based ER2220 product. As well as compact, miniaturised electronic assemblies, high thermal conductivity potting resins are now increasingly being sought for the protection of LED luminaires, an industry that in a few years has gone from virtually nothing to one that is currently experiencing exponential growth. The LED industry has also benefitted from developments in silicone and polyurethane resin chemistries, which can provide the necessary optical clarity as well as desirable light diffusing effects.

.....

“The LED industry has also benefitted from developments in silicone and polyurethane resin chemistries, which can provide the necessary optical clarity as well as desirable light diffusing effects.”

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Developments in the automotive industry—in particular, the growing availability of electric vehicles—have also seen demand for encapsulating resins with improved temperature stability, greater resistance to thermal shock and generally broader operating temperature ranges. Silicone resins, while they tend to be more expensive than their epoxy or polyurethane counterparts, are often the best choice for applications where high continuous operating temperatures (above 180°C) are expected, such as near electric motors and power electronics.

The volumes of resin used in an assembly are also more carefully calculated than in the past when the level of protection might have been improved by simply increasing the thickness of the coating or encapsulation. In the case of a modern smartphone, which puts extraordinary computing power in the palm of your hand, that simple expedient is no longer available to the design team, and size and weight considerations now dictate the application of much smaller volumes of resin with no compromise in terms of its overall electrical performance.

In meeting these requirements, the electrical properties of modern resin systems have improved significantly in recent years. New, so-called “ultra-high performance” polyurethane resins, for example, offer excellent electrical properties while also protecting devices from physical shock and vibration. These resins benefit from some of the latest developments in filler materials and particle dispersions that improve their dielectric strength, enabling thinner resin applications to deliver the desired electrical performance.

Environmental considerations and the health of production staff and end-users alike have had a huge impact on the material formulation of resins, which are now governed according to international regulations. These include the European Union's REACH regulation which has been in force since December 2006 and the RoHS-1 Directive, which was adopted in February 2003 by the European Union, now superseded by RoHS-2 in July 2011. Equivalent legislation outside of Europe includes the “Promotion of Clean Production” law in China and “Safer Consumer Product” regulation in California.

Clearly, these overarching regulations have had quite an impact on the way we chemists formulate our products and many of the raw materials that we used in the past, such as some specified heavy metals and solvents, are either banned or strictly controlled in terms of their concentrations. Since the introduction of these regulations, and like many of our colleagues in the industry, Electrolube has gone to great lengths to ensure all qualifying products are RoHS-compliant (some being exempt under the rules) and that all comply with current REACH requirements.

The list of substances covered by the comprehensive REACH regulation is continually being updated and full implementation is not expected to be completed for quite a number of years yet. To make sure our company is fully up to date with developments, we have established a REACH task force within Electrolube that works with our raw material suppliers and our customers to ensure full compliance with the regulation at every stage.

Over the last 20 years, various universities have conducted a lot of research into the way polymers age under a range of conditions, and how their various physical properties change over time. This has led to a better understanding of how resins behave in the longer term and has enabled us to specify appropriate resin systems and ensure that the products containing them will continue to function as intended over their design life and—increasing being demanded by our customers these days—well beyond.

So, what can we expect over the next 20 years? Prediction is proverbially a fool's occupation but, as a company, we do have some insights into the future needs of our custom-

ers. Looking forward, we believe there will be more demand for very high-performance resins that can tolerate higher continuous operating temperatures (180°C and greater), while being more resistant to thermal and physical shock and chemical attack. We are also considering increasing the sustainability of our resins.

We have products now that deliver these properties, but there's still plenty of research and development to do to "future-proof" our resins portfolio, so we can continue to stay one step ahead and provide advanced solutions when our customers need new resin solutions the most, in keeping with the rapid changes of the market. **PCBDESIGN**



Alistair Little is technical director of Electrolube's Resins Division.

Engineer Unveils New Spin on Future of Transistors with Novel Design

A researcher with the Erik Jonsson School of Engineering and Computer Science at UT Dallas has designed a novel computing system made solely from carbon that might one day replace the silicon transistors that power today's electronic devices.

"The concept brings together an assortment of existing nanoscale technologies and combines them in a new way," said Dr. Joseph S. Friedman, assistant professor of electrical and computer engineering at UT Dallas.

The resulting all-carbon spin logic proposal, published by lead author Friedman and several collaborators in the June 5 edition of the online journal *Nature Communications*, is a computing system that Friedman believes could be made smaller than silicon transistors, with increased performance.

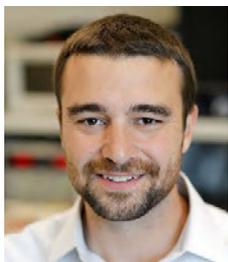
Today's electronic devices are powered by transistors, which are tiny silicon structures that

rely on negatively charged electrons moving through the silicon, forming an electric current. Transistors behave like switches, turning current on and off.

In addition to carrying a charge, electrons have another property called spin, which relates to their magnetic properties. In recent years, engineers have been investigating ways to exploit the spin characteristics of electrons to create a new class of transistors and devices called "spintronics."

Friedman's all-carbon, spintronic switch functions as a logic gate that relies on a basic tenet of electromagnetics: As an electric current moves through a wire, it creates a magnetic field that wraps around the wire.

Because the communication between each of the graphene nanoribbons takes place via an electromagnetic wave, instead of the physical movement of electrons, Friedman expects that communication will be much faster, with the potential for terahertz clock speeds.





Senior Salesperson— Automotive Electronics

CheckSum is a leading supplier of PCBA test and on-board programming systems and fixtures to the worldwide electronics manufacturing industry. Our technology sets the industry standard in high-throughput solutions for automotive electronics with innovative solutions that meet the quality, speed, and economic requirements of the industry. Founded in 1987, CheckSum is a profitable private company with a broad customer base and a large market opportunity.

Position: CheckSum is seeking a senior salesperson to help us add new automotive electronics customers. We will shortly launch a new technology solution to further our throughput advantage and open doors with new customers.

Requirements:

- Proven sales performer with a track record of landing new accounts and growing existing relationships
- Five years of experience selling CapEx electronic equipment required
- Experience selling automated board test equipment preferred
- General technical knowledge of electronics required
- Demonstrated ability to network to develop leads and multiple relationships at target accounts
- Salesforce fluency
- Strong communication skills
- Self-starter with a sense of urgency and an ability to work independently

Compensation: Negotiable depending on experience

Contact: Please send resume and cover letter. To apply, click below.

[Click here to apply](#)



ROYAL FLEX
CIRCUITS

Sales Professional \$200k Package

Royal Flex Circuits is a So-Cal-based company specializing in manufacturing Flex Circuits, Rigid Flex Circuits and HDI PCBs for the military, medical and consumer markets. Royal Flex enjoys a 30+ history in the PCB Industry and has just completed a \$2M investment in new technology (lasers, LDI, Vision Drilling, AOI, etc.) and new engineering & production talent which has positioned the company for the next 10 years.

We are looking for an experienced sales professional capable of bringing in new accounts north of \$3M per year. We are not interested in a behind the desk, theory spouting, strategy creating sales manager. We want someone that has been in the PCB industry, has strong relationships, and can bring in business.

We offer a generous base salary of \$120k per year, with an attractive commission program which should push the total compensation \$200k–\$250k. We have the best-in-industry medical, dental and vision insurance, with 90% of premiums paid by employer, as well as a fantastic 401k plan. Our biggest benefit is that we have a stellar reputation and incredible work ethic and integrity.

Please send resume and cover letter explaining why you are that perfect match for our company.

[Click here to apply](#)

CAREER OPPORTUNITIES



LENTHOR ENGINEERING
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311 Turquoise Street Milpitas, CA 95035 (Phone) 408-945-8787

PROCESS ENGINEER

Responsible for developing and optimizing Lenthor's manufacturing processes from start up to implementation, reducing cost, improving sustainability and continuous improvement.

Duties include but are not limited to:

- Participate in the evaluation of processes, new equipment, facility improvements and procedures.
- Improve process capability, yields, costs and production volume while maintaining safety and improving quality standards.
- Assist in employee training and certification.
- Work with customers in developing cost effective production processes.
- Engage suppliers in quality improvements and process control issues as required.
- Generate process control plan for manufacturing processes and identify opportunities for capability or process improvement.
- Participate in FMEA activities as required.
- Create detailed plans for IQ, OQ, PQ and maintain validated states as required.
- Participate in existing change control mechanisms such as ECO's and PCR's.
- Perform defect reduction analysis and activities.
- Participate in technology roadmap planning.
- Participate in new materials, processing or other developments as required.

Experience & Education:

- BS degree in Engineering
- 2-5 years of proven work experience
- Excellent technical skills

Competitive salaries based on experience, comprehensive health benefits package, 401(k) and Quarterly Gain Sharing bonus available to eligible employees.

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SALES ACCOUNT MANAGER

This is a direct sales position responsible for creating and growing a base of customers. The account manager is in charge of finding and qualifying customers while promoting Lenthor's capabilities to the customer through telephone calls, customer visits and use of electronic communications. Experience with military and medical PWB/PWA a definite plus. Each account manager is responsible for meeting a dollar level of sales per month and is compensated with salary and a sales commission plan.

Duties include:

- Marketing research to identify target customers.
- Initial customer contact (cold calling).
- Identifying the person(s) responsible for purchasing flexible circuits.
- Exploring the customer's needs that fit our capabilities in terms of:
 - Market and product
 - Circuit types used
 - Quantity and delivery requirements
 - Competitive influences
 - Philosophies and finance
 - Quoting and closing orders
 - Bonding
- Submitting quotes and sales orders.
- Providing ongoing service to the customer.
- Problem solving
- Developing customer information profiles.
- Developing long-term customer strategies to increase business.
- Participate in quality/production meetings.
- Assist in customer quality surveys.
- Knowledgeably respond to non-routine or critical conditions and situations.

Competitive salaries based on experience, comprehensive health benefits package and 401(k) Plan.

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Outside Sales/ Key Account Managers

Job Description: NCAB Group USA is looking to add to our existing outside sales team in various U.S. locations; Ontario, California and Itasca, Illinois. We are looking for sales professionals with at least 5 years of printed circuit board experience and/or semiconductor experience and knowledge. This is a sales position that requires the ability to convert those cold calls into high-value customer meetings.

What are we looking for?

- A “hunter” mentality
- The ability to create solid customer relationships
- A desire to excel and not settle for mediocrity
- 5+ years of experience in the Printed Circuit Board or Semiconductor industry
- An excellent ability to present your product and do the “deep dive” during your customer visit by asking the open-ended questions and identifying your customer’s pain points
- The energy to sell—from prospecting to cold calls to getting the “wins”
- Knowledge of “SPIN” selling
- A college degree
- An enjoyment to travel both domestically and globally
- Must be a U.S. citizen with a valid U.S. Passport

What’s next? Interested?
Then send your resume to:

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OUTSIDE SALES REPRESENTATIVE
Entry-level candidates welcome

Job Description: Grow business by setting up meetings with customers and handling presentations, selling products, and meeting customer needs. Required to meet customers face to face on weekly basis.

Territory: All states and parts of Canada.

Skills/Qualifications: Great communication skills; customer hospitality; meeting sales goals; closing skills; territory/account management; prospecting skills; negotiation; travel scheduling; computer and network skills (intermediate level); self-confidence; presentation skills; client relationships; motivation for sales; motivation to learn; loyalty to company; respect to customer and team member; patience; due obligation.

Plus Aspects:

- Bachelor or higher degree
- Experience in outside sales
- Knowledge of print circuit boards

MicroCraft offers:

- Domestic travel allowance
- International travel allowance
- 401(k) with company match
- 90% coverage on health insurance and dental insurance for the employee
- Life, AD&D, short term and long term disability for the employee
- PTO and holidays
- Good environment/helpful coworkers
- The opportunities to expand your knowledge

Salary: \$40,000 to \$75,000 or more. Your salary depends on your sales performance. This figure includes sales commission.

[Click here to apply](#)

Contact: Kohei Maekawa

CAREER OPPORTUNITIES



Arlon EMD, located in Rancho Cucamonga, California is currently interviewing candidates for **manufacturing** and **management positions**. All interested candidates should contact Arlon's HR department at 909-987-9533 or fax resumes to 866-812-5847.

Arlon is a major manufacturer of specialty high performance laminate and prepreg materials for use in a wide variety of PCB (printed circuit board) applications. Arlon specializes in thermoset resin technology including polyimide, high Tg multifunctional epoxy, and low loss thermoset laminate and prepreg systems. These resin systems are available on a variety of substrates, including woven glass and non-woven aramid. Typical applications for these materials include advanced commercial and military electronics such as avionics, semiconductor testing, heat sink bonding, high density interconnect (HDI) and microvia PCBs (i.e., in mobile communication products).

Our facility employs state of the art production equipment engineered to provide cost-effective and flexible manufacturing capacity allowing us to respond quickly to customer requirements while meeting the most stringent quality and tolerance demands. Our manufacturing site is ISO 9001: 2008 registered, and through rigorous quality control practices and commitment to continual improvement, we are dedicated to meeting and exceeding our customer's requirements.

[Click here for more details](#)



Advanced technology manufacturer of printed circuit boards in Huntington Beach, CA is looking for manufacturer's representatives in Southern California. Please forward inquiries to Crystal Barrett. (585) 254-2989 ext. 225

[Click here to apply](#)



all flex
Flexible Circuits • Heaters • Assemblies

HELP WANTED

In order to support its continued growth and leadership position, All Flex Flexible Circuits and Heaters is seeking a TECHNICAL APPLICATION SALES ENGINEER for our inside sales team. Candidates are to have 5+ years in the PCB industry including a minimum of 2 years with flexible circuitry and/or flexible heaters. Experience in component assembly and flexible heater design is a plus.

The position involves providing extremely high responsiveness and follow-up to assigned accounts and new prospect inquiries. Although primarily an inside sales service provider, the individual must also be able to travel several times per year to support tradeshow and in-person customer support. The position provides technical application knowledge to assist customers in the design and use of flexible circuits, heaters, and assemblies, a key service that All Flex provides.

Background to include:

- Success in a team environment
- Managing large customers – ideally in medical, military, aerospace, and industrial markets
- Proficiency in Microsoft Office Suite with good typing/keyboard skills
- Attention to detail
- Good organization skills in handling multiple activities at the same time
- Professional telephone and e-mail communication skills
- Experience working trade shows
- Good listening and customer management abilities

This position is located in Northfield, MN.

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INTERNATIONAL GROUP
騰輝電子

OEM Account Manager USA (IMS Materials)

Want to work for a globally successful and growing company and help drive that success? As a US-based key member of the global OEM Marketing Team, your focus will be on IMS (Insulated Metal Substrates) materials that deliver exceptional thermal performance, reliability and quality, particularly demanded by automotive and other LED lighting and DC power conversion applications. Combining your strong technical PCB manufacturing and design knowledge with commercial acumen, you will offer OEM customers (buyers, designers, reliability engineers and the people that liaise directly with the PCB manufacturers) advice and solutions for optimum performance, quality and cost.

Skills and abilities required for the role:

- Technical background in PCB manufacturing/design.
- Solid understanding of IMS Materials.
- Sales knowledge and skills.
- Excellent oral and written communication skills in English.
- Experience in making compelling presentations to small and large audiences.
- Proven relationship building skills with partners and virtual teams.

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits.

Please forward your resume to:

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Mention "OEM Account Manager USA" in the subject line.



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Experienced Sales Reps Needed

Candor is an advanced printed circuit board manufacturer with a unique manufacturing process. We can genuinely stand out among conventional board shops due to our unique Simplified Process.

Join the Candor team, targeting rapid high quality prototype PCB manufacturing.

We are looking for industry experienced sales reps to manage current customers and find new leads in the USA. Candor is in a unique position to hire onto our team using a very generous sliding commission rate. Contact Sunny Patel for details.

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CAREER OPPORTUNITIES



ZENTECH

Zentech Manufacturing is Hiring!

Looking to excel in your career and grow professionally in a thriving business? Zentech, with locations in Baltimore, MD and Fredericksburg, VA is rapidly growing and is seeking experienced professionals in all areas: engineering, manufacturing engineering, program management, testing, QA and SMT operations. Zentech offers an excellent benefit package including health/dental insurance and an employer matched 401(k) program.

Established in 1998, Zentech holds an ultimate set of certifications relating to the manufacture of mission-critical printed circuit card assemblies, including ISO:9001, AS9100, DD2345, ISO 13485, maintains an IPC 610 Trusted Source QML status, J-STD 001 with Space Certification and is ITAR registered.

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PCB Front End CAM Engineer

Associates degree or better is required. Must have a minimum of 3 years of experience working for a printed circuit board manufacturer. Must have Valor Genesis software experience. Scripting knowledge is beneficial but not required. This is a full time salaried position on 1st shift. Pay commensurate with experience.

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MivaTek

Global

Application/Sales Engineer

Positions available Eastern, Midwestern and Western United States. Position will focus on supporting sales and applications development for Miva Technologies DLP direct imaging system with the PCB and micro-electronics markets. Experience with photoresist and imaging preferred but not required.

Service Technician

Positions available for Eastern and Western United States. Service technicians will support our rapidly expanding installed base of Miva Technologies DLP imaging systems as well as other systems sold by the company.

Send resume and contact information for both positions to Brendan Hogan.

[Click here to apply](#)

TOP TEN



Recent Highlights from PCBDesign007

1 **Mentor OSAT Alliance Streamlines IC High-Density Advanced Packaging Design and Manufacturing**

Mentor has launched the Mentor OSAT (Outsourced Assembly and Test) Alliance program to help drive ecosystem capabilities in support of new high-density advanced packaging (HDAP) technologies like 2.5D IC, 3D IC and fan-out wafer-level packaging (FOWLP) for customer integrated circuit (IC) designs.



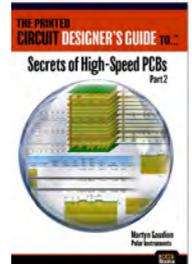
2 **SnapEDA: Recruiting Top Engineering Talent in an Amazon World**

You don't have to love EDA to work at SnapEDA, but it helps. This startup, founded by Natasha Baker, is on its way to creating the world's largest parts library for PCB designers. Baker leads a small team of young, fiercely talented engineers—the kind of employees that are attractive to companies like Google and Facebook. I asked Natasha to explain her hiring process, and how she ensures that each employee is the right fit for SnapEDA.



3 **I-Connect007 Launches "The Printed Circuit Designer's Guide to...Secrets of High-Speed PCBs – Part 2" Micro eBook**

The latest title in this new line of eBooks, The Printed Circuit Designer's Guide to... Secrets of High-Speed PCBs – Part 2, is authored by Martyn Gaudion of Polar Instruments. Following on Part 1, this edition examines issues such as laminate loss, differential insertion loss, impedance control, modelled vs. measured results, and much more.



4 **Steve Robinson Discusses APCT's Tenfold Expansion**

Steve Robinson, CEO of APCT, a PCB fabricator in Silicon Valley, has led the company to impressive growth since he acquired it nearly 10 years ago. I ran into Steve at DesignCon 2017, and we sat down to discuss the company's remarkable transformation and his focus on working with PCB designers and engineers to create advanced, high-speed PCBs.



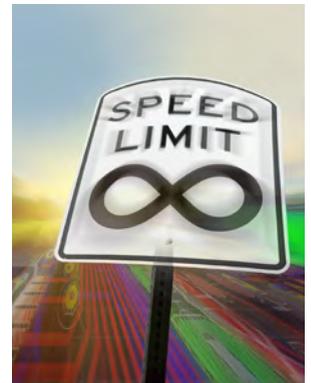
5 Intercept Technology Makes Strides with New Pantheon PCB/Hybrid/RF Layout Software Version

Intercept Technology has launched a major new enhancement release of its Pantheon PCB layout software, which includes specialized RF and hybrid design flows. Complementing this new Pantheon version is a major enhancement release of Intercept's Mozaik CAE schematic design software.



8 The State of High-Speed Materials

Choosing the right material for your PCB was so simple a few decades ago. All but the most high-tech PCBs were constructed with FR-4. The lowly FR-4 has been improved and re-engineered many times in the past few decades, and rumors of its demise have proven unfounded.



6 Altium Focuses on the Designer First

A few months before I joined Altium, while I was still with I-Connect007, I sat down with Lawrence Romine to discuss the company's drive to satisfy the individual PCB designer, and not necessarily the OEMs who employ them. Romine also explains what sets designers and engineers apart from the average person, and why some Altium users have a different primary EDA tool, but use Altium when they need a design done fast.



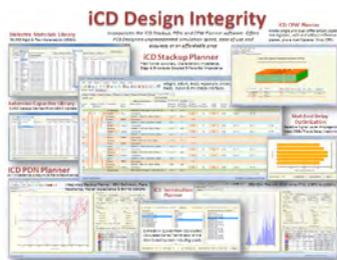
9 Ucamco Releases Integr8tor v2017.05

Ucamco has announced the release of version v2017.05 of Integr8tor, the market-leading data entry and design analysis tool for sales, pre-CAM and engineering. This version builds further on the v2016.12 release from last December.



7 iCD Launches QuickSolver Edition of Stackup Planner

The iCD QuickSolver is an inexpensive edition of the popular iCD Stackup Planner that is powered by the same precision 2D BEM field solver and provides everything you need to accurately model the characteristic and differential impedance of multi-layer PCBs utilizing blind and buried vias.



10 Beyond Design: Return Path Discontinuities

Simultaneous switching noise (SSN) is a major problem in high-speed systems. But the underlying issue is really the management of transmission line return currents that flow on the nearby reference planes, causing the planes to bounce. High-speed design is not as simple as sending a signal from the driver to the receiver, over an interconnect.



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Events



For IPC Calendar of Events, [click here](#).

For the SMTA Calendar of Events, [click here](#).

For a complete listing, check out The PCB Design Magazine's [event calendar](#).

[FLEX 2017](#)

June 19–22, 2017
Monterey, California, USA

[IPC Reliability Forum: Emerging Technologies](#)

June 27–28, 2017
Düsseldorf, Germany

[PCB West](#)

September 12–14, 2017
Santa Clara, California, USA

[24th FED Conference](#)

September 15–16, 2017
Bonn, Germany

[SMTA International 2017 Conference and Exhibition](#)

September 17–21, 2017
Rosemont, Illinois, USA

[electronicAsia](#)

October 13–16, 2017
Hong Kong

[IPC Flexible Circuits: HDI Forum](#)

October 17–19, 2017
Minneapolis, Minnesota, USA

[TPCA Show 2017](#)

October 25–27, 2017
Taipei, Taiwan

[productronica 2017](#)

November 14–17, 2017
Munich, Germany

[HKPCA/IPC International Printed Circuit & South China Fair](#)

December 6–8, 2017
Shenzhen, China



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COVER IMAGE: **PIMMIMEMOM, ADOBE STOCK**



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June 2017, Volume 6, Number 6 • The PCB Design Magazine© is published monthly by BR Publishing, Inc.

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