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HIGH-SPEED MATERIALS

April 2017

THE PCB DESIGN MAGAZINE

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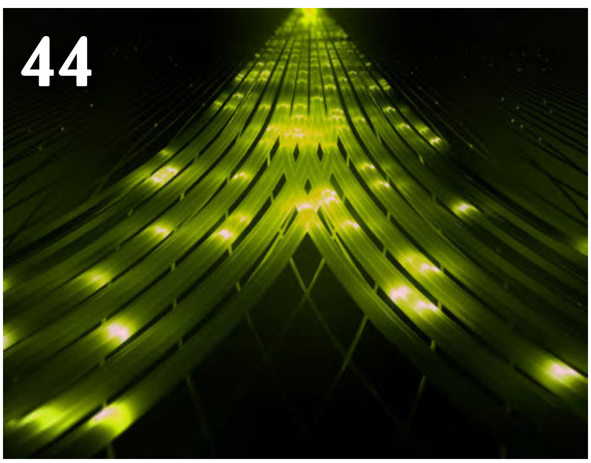

The High-Speed Materials Issue

Choosing the right material for your PCB was so simple a few decades ago. But today, designers often must select an advanced low-loss PCB material with low Df and Dk values—hopefully one that isn't prohibitively expensive or terribly difficult for fabricators to register during lamination.

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More Content

The State of High-Speed Materials

by Andy Shaughnessy
I-CONNECT007

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.

But at today's high speeds, FR-4 often doesn't measure up, and designers must select an advanced low-loss PCB material with low Df and Dk values that isn't prohibitively expensive or terribly difficult for fabricators to register during lamination. High-speed PCB signals now exhibit characteristics previously seen only in the RF and microwave world, requiring PCB designers to consider using lok-Dk RF materials such as PTFE and Teflon, which are much "softer" than FR-4 and tougher for the fabricator to work with.

We started out with a reader survey. We asked, "If you are a PCB fabricator or designer, what are the greatest challenges for you working with high-speed materials?" and some of the answers were quite interesting.

Answers included:

- Dielectric constant is too high
- Material movement
- Getting accurate performance data
- Customer knowledge
- Performance for signal integrity
- Getting accurate dielectric material properties from data sheets
- Availability
- Too many materials to stock
- Mechanical stability in the z-axis
- Materials adhesion
- As a PCB fabricator, understanding designers' needs
- Hole wall quality
- Educating the customers on what they actually need
- Impedance control
- Lead time
- Cost

Many of the fabricators' biggest challenges were related to manufacturability. The more

high-tech materials are softer and pose problems with adhesion and registration. But many of the problems cited by designers centered on the lack of good data for advanced materials. Designers say they have a tough time finding material properties, much less simulation models, for high-speed materials.

Why? It can take a year or more for a new material to be launched, so many PCB materials are released without being fully tested and characterized. When electrical engineer "gurus" in our industry publish their own property measurements on a newly-released high-speed material, the design community (not to mention the material supplier) is happy to have the information.

As one designer summed it up, "Materials suppliers need to do a better job." If designers had all the information they need about each type of material, they could do a better job of educating their customers at the OEMs about "what they actually need," as another respondent put it.

So, this month, we feature interviews with a variety of experts. Summit Interconnect's Gerry Partida and All Flex Flexible Circuits' Joe Menning spoke with our editorial team about the state of advanced materials from the fabricators' viewpoint. Craig Davidson of TTM explains the company's pursuit of embedded optical interconnect and the challenges surrounding optical PCBs. Bruce Mahler of Ohmega Technologies examines Ohmega's resistive material technology and some of the drivers and issues in that segment of the industry. And APCT's Steve Robinson discusses his company's focus on working with PCB designers and engineers to create advanced, high-speed PCBs. Plus, columnist John Coonrod of Rogers Corporation discusses some of the challenges and remedies for woven glass weave effect.

In addition, we bring you columns by our regular contributors, Barry Olney of In-Circuit Design, and Alistair Little of Electrolube. We also have Judy Warner's interview with Altium's Lawrence Romine, who explains why this EDA company prefers to focus directly on the PCB designer and his needs. And we have an article about the upcoming TIE PCB design conference in Romania, which features a PCB design contest that draws engineering students from across Romania.

Show season is slowing down, but I'll be at SMTA Atlanta in Duluth, Georgia, on April 19. The PCB Designers Roundtable is always a real treat, like a psychiatrist's couch, as one attendee once described it. If you're in metro Atlanta, check it out.

See you next month! **PCBDESIGN**

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.

Super Microscopes Help Make Greener Batteries

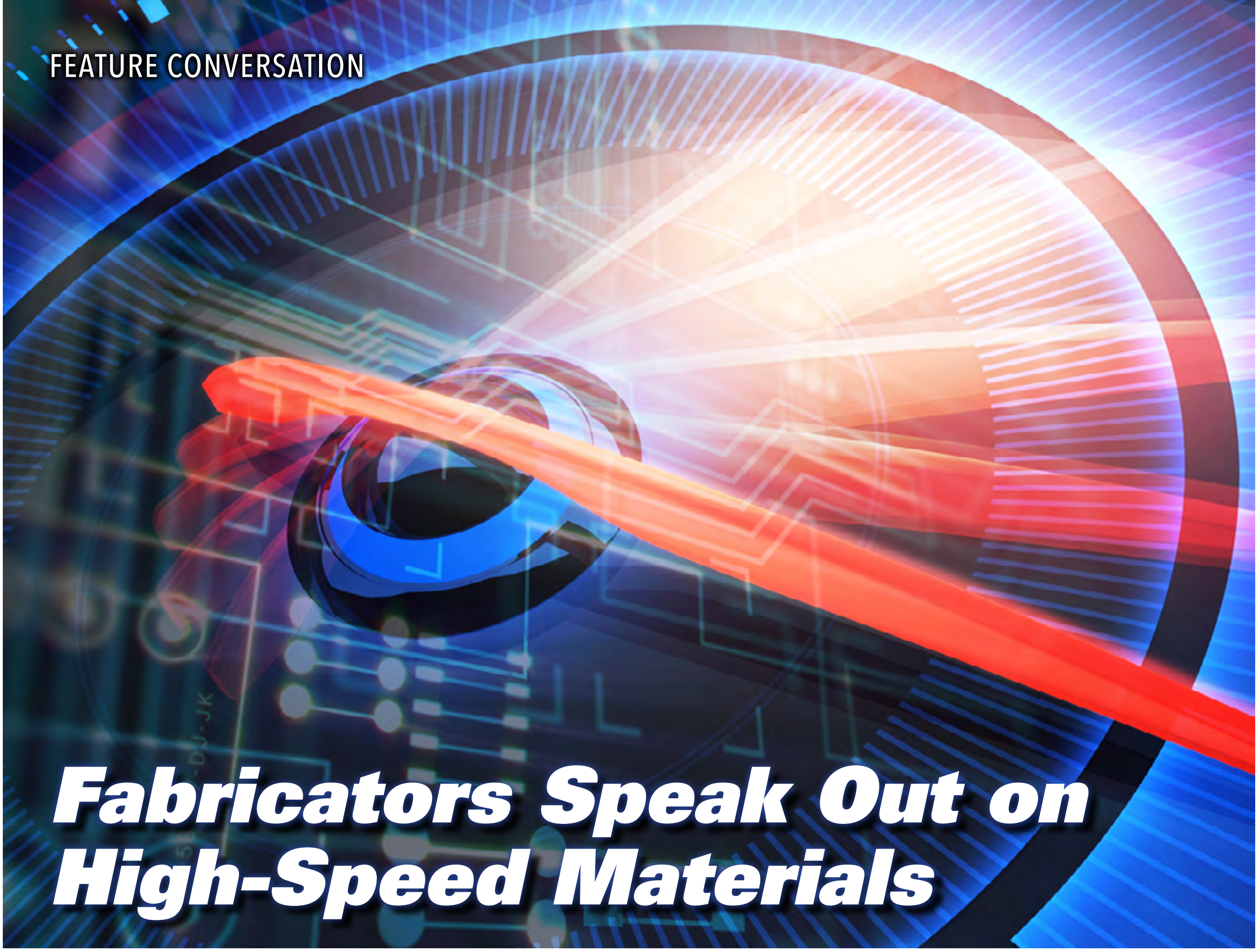
Scientists at NTNU and SINTEF are working intensely to move battery development several critical steps forward. The difference between an ordinary optical (or light) microscope and a transmission electron microscope (TEM) is huge – or in reality, quite miniscule. An ordinary optical microscope has a magnifying power up to 2,000 times. An electron microscope can magnify a further 2,000 times – or 4 million times.

Electron microscopy offers battery researchers another important feature: they can see the types of atoms in question—in other words, the chemical composition of the material.what the material is.

Is the specimen that scientists are observing in the microscope arranged in certain patterns, or are the atoms more randomly distributed? The organization of the atoms in the battery components can actually change when the battery is used. The electron microscope makes it possible for scientists to also study the battery's behaviour and material while it is being used.

Where are the atoms and how do they bond to each other? What connections do they form before testing? Where are the different atoms and what constellations do they create at the end of testing? And last but not least – what happens to the atoms when battery power begins to decline? Scientists use what they learn to adjust and set up the next testing.

FEATURE CONVERSATION



Fabricators Speak Out on High-Speed Materials

by I-Connect007

Recently, I-Connect007 Publisher Barry Matties and his editorial team joined with two PCB fabricators to discuss the state of advanced materials. The meeting included Gerry Partida, director of engineering at Summit Interconnect and Joe Menning, program manager at All Flex Flexible Circuits. The discussion centered on the processes, challenges, and procurement of high-speed materials, as well as the need to work with customers during the design stage.

Patty Goldman: ***We are here to talk about high-performance and high-speed materials. We've spoken with a few laminate suppliers, but we also wanted to get the viewpoint of the guys making the boards. We asked you to join us so we can find out how fabricators are dealing with these materials, what you need from suppliers, what you think our readers should know about advanced materials.***

Barry Matties: ***When we start talking about high-speed materials, what are the greatest challenges you face with high-speed materials, from procurement to processing and delivery? Maybe even from OEMs specifying materials or not? Gerry, why don't we start with you.***

Gerry Partida: Thank you for allowing us to share this. This is very important stuff. A lot of the RF materials are very hard to register when you laminate or process the materials. There are many RF materials that are not glass-reinforced or very loosely glass-reinforced. When we planarize the material for epoxy fill, or blind via lamination structures and we epoxy fill, the material stretches out. We call some of it bubble gum because you can just distort the material as you planarize an epoxy-filled via. Also, the material just moves a lot, in some cases three times greater than standard glass-reinforced epoxy materials.

That's one of the biggest challenges—maintaining registration and controlling it, knowing where it's going to end up. The material is very expensive. I like to use the analogy with people that building FR-4 boards, regular, digital or something that's straightforward versus

an RF board is like playing craps. The difference between FR-4 boards and RF boards is that the FR-4 boards are like playing craps Saturday night in Laughlin, Nevada, which is a $5 minimum bet, where RF is like playing the Bellagio at 9 o'clock on Saturday night where the minimum bet is $25. Same rules, same game, but the buy-in is huge because of the registration and the other fun stuff that goes with it. You can lose fast or you can win a lot.

Gerry Partida

That's one of the greatest challenges—the material itself, its softness, its registration, as well as processing. One of the things is holding registration and the material. The other parts that are a challenge for the materials are the ability to deposit electroless and maintaining peel strength. A lot of them have low peel strength. Many RF materials can have smear. We call it flat, but it's smear when you drill and you cover the inner face of an innerlayer pad; it violates the IPC-6012 rigid PCB performance spec. It's allowed somewhat in IPC-6018, the performance spec for high-frequency/microwave PCBs—but smear is always a concern on a lot of high-speed materials.

Some of the other challenges with materials are Teflon or PTFE surfaces, where you have to do special treatment to get the soldermask or legend to stick to it.

***Matties:* When you talk about the registration, how do you mitigate the problem?**

Partida: What we do is we use software that collects data on every panel we build, every resin system, and every lamination cycle. This information is a feedback system to predict future builds to be on target the first time, to reduce the risk of losing material. Sometimes, if we look at a structure we've never seen before, we'll do a pilot run to dial in the scale factors, or we work with a customer saying, "You know, you want a Class 3 board but this is an engineering board. Can we have Class 2 as we learn the scale factors for this construction and this stack-up?" Sometimes they'll work with us on that.

The RF community really works very well with the printed circuit board manufacturers. We have to work together in order to be successful, so we use those tools. The other challenge, too, with a lot of the high-speed RF materials or parts is that there are unbalanced constructions. For example, one of the first boards we built was a 1 to 2, 1 to 5, 1 to 7, 1 to 9, 1 to 11, 12 to 14 and then final 1 to 14 lamination structure. With our predictor, we got on target the first time.

***Matties:* Wow. Is this over-the-counter software or is this proprietary software that you've developed?**

Partida: It's a software that I believe won an award at the APEX show, three or four years ago, for the best product of the show. The company's name is XACT PCB. When you're working with high-speed RF with high frequencies, there are so many different combinations of materials that the engineers use that you're always challenged, whether you have it in your database or you're learning for the first time, in which case the predictor tells you, "I've never seen this before. Good luck."

***Matties:* What about from the flex side, any challenges for you, Joe?**

Joe Menning: On the flex side of things I would echo a lot of the same concerns. Even though we don't do a whole lot in the high-speed materials area, I'd echo the concerns on the processing. Obviously in the flex world we're used to materials moving and changing shape, but I would reinforce the fact that a lot of the high-speed materials that we've had experience with are even more challenging than typical flex materials. Regarding the comment about PTFE, it's a great high-speed material but it doesn't bond well to anything, really, unless you have some sort of pre-treatment, so it's got a lot of challenges on that front.

***Matties:* In the flex world, you've been dealing with material movement for a long time. How do you deal with the registration issue?**

Menning: For us, it's about really understanding your base materials and how they move. Unlike Gerry, we don't have the software to monitor it in real time, but we try to limit the number of base material configurations we have and, when necessary, we'll do engineering evaluation runs to develop scale factors so that we can predictably scale the artworks to compensate for that shrinkage.

***Matties:** A lot of the new process equipment can make modifications on a per-board basis. They're finding best center for alignment and x-rays and that sort of thing for drilling the optimum hole. Is that technology what you guys are seeing and utilizing?*

Partida: We're using that with the XACT software, so what it does is not only tell you how far off the layers the registration is, it tells you what to do for the next time you build that same panel or tool. It will put in brand new tooling to square up the panel so that all of them will pin to the drill machine consistently the same. So if there is any variation, it kind of zeroes in on the variation of each panel and squares it up.

***Matties:** Per panel. I understand you're pushing lots through, but when you're processing a panel, making modifications to individual panels, that really brings it down to that lot size of one mentality though, doesn't it?*

Partida: What it does is it gives them all the same zero tooling on all the panels. If one is, let's say, slightly rotated half a degree to the right and the other one is half a degree to the left, one is shifted down one mil, one is shifted up one mil, when the new tooling goes in they've all been squared to each other back to one zero. It improves registration tremendously when you go and drill on the machines. Rather than having random pinning now you have brand new pristine tooling, pristine, never-used, and they're all squared up with each other and it is a big boost in final registration and cross-sections for meeting annular ring.

***Matties:** Regarding tooling, there are the pin systems and the pinless systems. Have you explored both of those and do you have any opinion on those, for the registration issue?*

Partida: I have an opinion on the pinless one. What they do is they weld the outside of the panel core to core through the pre-preg through heat, but I don't subscribe to the theory. Cores will shrink. The different glass styles or the glass weave in a core is what's going to allow that core to shrink and the pre-preg is the activator that moves it. If you have a 14-core 2-ounce over 2-ounce and a 3-core signal, they will want to move differently.

You can't weld the outside and tell them to stop and not do it. I don't believe that works. With the information we have with our registration software, we track our yields and we know how many panels we scrap, when I tell the folks with the pinless system, where they align the cores, the number of panels we scrap per year, they're shocked at how low it is. It's not a problem. We scrap less than 12 panels a month for missed registration.

I don't see the need to change the system that's been working tremendously for us with jobs that have no reinforcement and multiple lamination cycles. As long as we have a prediction of what it will move, it generally will keep us in a safe location when we're done laminating. It took about two and a half years to put the whole system together, the complete feedback system, but it's a wonderful system.

***Matties:** That's great. It sounds like you guys have really put a lot of thought into this. It's never easy, you know. It's 90% planning and then once you implement it you just reap the benefits for years to come.*

Partida: I think that's what has helped us to be successful with the RF community. It's very critical that these features are where they're supposed to be for the best performance. In RF, you could look at it cross-eyed and it will act different or act funny. We've been working with RF materials, but it was mostly for semiconductor customers. When we started with the RF community about 9 or 10 years ago, customers would call us back and ask, "What are you doing?" and we'd say, "What do you mean?" "All the parts look exactly the same." I'd say, "Aren't they supposed to?" They'd say, "Yeah," and then they'd giggle.

It's process control. If a board shop doesn't have process control and they run panels through the etcher at different times for the same lot, if they run one core through the oxide multiple times but not the other cores in the same lot, if they laminate at different times for the same lot, if they run through the electroless and do some re-work, if we do all this variation to process, at the end there is not one panel that was processed like the other panel in that lot. That's the variation the RF guys just pull their hair out on.

You've got to have process control from beginning to end. You want to have the finished product behave the same from board to board, panel to panel, lot to lot.

***Matties:** Yeah, that's the ideal, is having them identical. But it's a rarity for sure.*

Partida: I don't want to forget; there are a lot of exciting laminate materials coming out that are processed like FR-4. Megtron 7, Megtron 6 is pretty good for a lot of RF. Megtron 7 will be great. Isola has I-Tera, Astra, Tachyon, that we're seeing customers using in the RF world. We don't have the processing issues of PTFE materials where we have to use particular plasma cycles. It's low peel-strength and you can't etch it back. These new materials have almost the same performance as the PTFE but they're glass-woven and so they're more stable.

"These new materials have almost the same performance as the PTFE but they're glass-woven and so they're more stable."

We can control the registration. We don't have to go through difficult plasma cycles to deposit electroless copper in the holes. We can planarize the boards without distorting the panel. There are more selection and dielectric sizes in these new materials that are coming out, which are giving the RF community options it did not have before because they had to use a certain bond ply in a certain location or a certain core in its location. Now they can use very different core thicknesses and use pre-preg and core interchangeably in a stack-up as needed.

***Matties:** So, this offers a lot of flexibility?*

Partida: It really, literally opens up. There were things that required using a core and the registration had to be perfect and they moved a lot, and there was just no way you could make it happen. Now you can just use a pre-preg and a foil and there's no chance of misregistering and you just register to the innerlayers through your precision registration software and you can dial in your drill into that one critical core and you can now do things you couldn't do before. This new material is pretty exciting. It's been out for about two or three years, which is new to the electronics industry but they seem very promising. For some of the RF PCBs that have been built, I've heard excellent feedback from our customers, who say, "We built the first board and it worked, we matched the other boards to the same configuration and they all fired up exactly the same ..." Then when you respond with, "Doesn't this always happen?" And they say, "No, it doesn't always happen."

***Matties:** You know it doesn't always happen when you ask that question; it's just fun to ask.*

Partida: And you want the feedback on the new materials too, right?

***Matties:** Yes. We've talked to some of the material suppliers and one of their big issues is the length of time that it takes to get new material approved. They're saying it could be a multi-year process to get a new material approved into the workflow. How does that impact your material selections? We know that some of the material is being used before it's approved by Cisco or some of the recognized vendors.*

Partida: For the military industry, they're not going to use anything that hasn't been approved and it's official. There is a required amount of time they have to continue to produce it, so the laminate suppliers want to make sure that it's done. When you're dealing with the end customer, especially military, it has to be an established product. We're fortunate enough that for many years we tested the material with different laminate suppliers before it even had a part number. So they paid us to laminate the boards and we're getting paid to learn how to use the material, and then we get all the feedback on how well it performs. We've been fortunate as a company to benefit from this relationship for about six or eight years.


Joe Menning

Menning: On the flex side, most of our materials are coming from people like DuPont or Panasonic and we kind of operate the same way. If we've got a customer need that doesn't fit into the current available material set, we'll work closely with those suppliers on new materials and do evaluation runs for customers to help them get comfortable with these materials that are new to the world. From our end, a lot of the requests are surrounding not so much high-speed but high-temperature. Traditional acrylic adhesives typically would work up to 150°C, and if we get customers like downhole drilling applications, where it›s really high-temperature applications, it pushes into new material sets where traditional acrylic adhesives would not survive. Those high-temp materials also are of value to us in our flex heater business and we also can combine flex heaters with flexible printed circuits for applications where they want a localized heat source and they also want to have high-temperature durability in the remainder of the flex circuit.

Matties: With the amount of new materials coming into the marketplace, how difficult is it to get a customer to try something? So many of them have specified their brands and stick with them. Are you finding they're motivated to change?

Partida: I think a lot of times when they're stuck in a design where the existing materials are not working for them, whether it's registration, dimensional, or they can get the right dielectric thickness, then they're open to it. Again, as I said earlier, the RF community is the most open-minded to suggestions and working with fabricators that I've ever seen in the electronics industry, and I've been in it for 30 years. It's fun to walk into a room with literally 10 PhDs and they ask you good questions. They're very enthusiastic about working together and trying different methods to solve a problem. They're open to new materials, but when they have a product that's been used in a particular construction or material selection and they're just making small modifications to it, they will not deviate from it because they know it works.

Matties: They know it works and they're not going to be driven by a few dollars on pricing when they know it works.

Partida: Right, I would say that's a very accurate way of stating that, yes.

Goldman: You both talked about pre-treating something like a PTFE, and I was wondering, what you do to stabilize that or how do you have to pretreat those very smooth surface materials?

Partida: In most cases, plasma will work with the hydrogen cycle at the end and then a purge. This will make the surface sticky so the electroless will attach to it. Sodium etch will have the same effect. Even soldermask and legend, it's so slippery a surface you can put soldermask down and tape test it and it will peel every bit of it off during a tape test. You have to activate the surface and (we like to use real technical terms in fabrication) to make the surface sticky and then the soldermask will adhere to it.

Menning: Yes, we do the same on the flex side. The plasma treatments are typically what we would use for activating the surface. The trick, of course, is that those treatments tend to be transitory or time-based. So it basically changes the chemical surface or creates available bond sites on the surface of the material, but if you don't do your coating or laminations or solder mask very shortly after that process, it will deactivate in open atmosphere. So you've got a short time window to take advantage of that treatment.

***Matties:** I was talking with Alex Stepinski over at Whelen Engineering. He said by not letting your work queue up, it actually saves so much process time and, exactly what you're saying, it just makes good sense to not let your boards queue up and sit around. You're making that case too.*

***Andy Shaughnessy:** Gerry, we've talked to these laminate suppliers over the years and they've said recently that they're working on the next sort of midway high-speed material, something that has the pros of PTFE without any of the cons as far as manufacturability. Are you all seeing any more of these sorts of high-speed laminates that have the processability of FR-4?*

Partida: Yes. Megtron 7, Megtron 6, Isola's Astra, I-Tera and Tachyon. They're being used and they're performing very well. It also has 4000-20 I think, or 4350-20, that seems to be not as popular as the other ones but it is getting some traction.

***Shaughnessy:** That's good to hear. They were really pushing for this. In the last couple of years, they said they had many people that just automatically would ask for PTFE and would over-constrain and would end up making the boards twice or three times more expensive.*

Partida: Yeah, that's when you lose big in Bellagio.

***Matties:** Go outside and watch the water show. Is there anything else that we should be talking about that we haven't covered yet regarding high-speed materials?*

Partida: I think one of the things you'll see more in the high-speed materials is a lot more critical GD&T (geometric dimensioning and tolerancing). They'll have very critical etch launches that they line up to tooling for other features. For the internal cut-out for an etch launch they have a very smaller tolerance than you normally see in a printed circuit board so those sometimes can be a challenge. You have to use precision rout machines so you would line up to the etch features before you do an etched, routed feature or a cut-out on a board based on where the etching pattern is at so that you're within a 2-mil window in some cases. That's getting pretty tight.

Menning: On the flex side, it's not necessarily for high-speed, but a lot of times we'll end up doing extended length circuits north of 100 inches that are flex and obviously registering a traditional coverlay layer that's routed to that image pattern is pretty difficult. One of the tools that we're using more and more often now is we'll lay coverlay over the whole pattern and we'll use a local registration feature near the critical areas of the flex and we'll laser ablate the coverlay off and then use a plasma to plane off the carbon. That way we've basically taken away the need for a scale factor and the coverlay will to match the etched feature, much like Gerry was talking about.

***Matties:** A lot of moving parts in all of this, that's for sure.*

Partida: That's the challenge, isn't it?

***Matties:** You know, there are just so many variables that it's hard to think that people can produce quality boards time after time after time.*

***Goldman:** I would guess it's also a moving target because you don't get to sit back and say, "Well, we're set for the next year with this particular style of something or other or this material." Everything's moving forward all the time.*

Partida: Right. The usage of RF and the demand for it, especially the military and even commercial, it's just going to keep growing in a very big way.

Matties: ***Oh, we're seeing it everywhere. I'm sure you're starting to see it in your factories too and with the equipment talking to each other and so on. This is really a fast-moving time. I certainly appreciate you gentlemen taking the time today to share your thoughts and insights with us.***

Goldman: ***This ought to help our readers a great deal.***

Matties: ***Our whole point is how do we help the industry improve overall and you guys are helping with that and it's good for all of us to have a strong industry, so thank you.***

Partida: Yes. Thank you.

Menning: You're welcome. **PCBDESIGN**

Ray Pritchard Looks Back at IPC's Beginning and His Role in Getting it Started

I have known Ray Pritchard for a long time—as long as I've been involved with IPC, in fact. He directed the organization for 35 years before turning over the reins. One could say he grew up with the organization—or vice versa. Ray was always a bundle of energy and still is, still joking and warm; he is a great people person, and I am sure he had a little something to do with the spirit of camaraderie and cooperation that is the hallmark of the IPC organization we know today.

That's why it was such a pleasure to sit down with Ray Pritchard in a quiet corner during this 60th anniversary year and listen to him talk about his early involvement in getting a fledgling organization, with just a handful of members, off the ground and running.

Patty Goldman: ***Ray, it is so wonderful to see you. The founding members brought you in to run the organization back in the beginning, am I correct?***

Pritchard: That was an interesting story. These young entrepreneurs, they were a new industry. Nobody knew them. Nobody had heard of printed circuits at the time, because everything was plugged in with wires.

They were meeting in Chicago at the Palmer House in 1957, and they said, "You know, we'd like to have a trade association. We've got all these problems. We don't know what to do about them." Somebody said, "Why don't we look in the yellow pages and find a professional high-class organization that could help us?"

Our company was right next door. It was called H.P. Dolan and Associates. It sounded professional, like there were all kinds of people, but I was the "associates." Harry Dolan at that time was out of the office, so Gene Jones and Bill McGinley walked in, and I'm sure when they saw this young-looking kid—though I was 30 years old—they thought, "What are we doing here?"

I'd made a flip chart showing things we had done for the six associations we were working for, and they were all manufacturing associations, so they all had needs for standards and technical work and improving the technology and all that. Then they needed market data, and they needed all kinds of things, but we'd done them all. So they saw my chart flipping, and they said, "Come on over to the Palmer House, and we'll talk to you about what you might be able to do."

[Click here](#) to read the full interview.

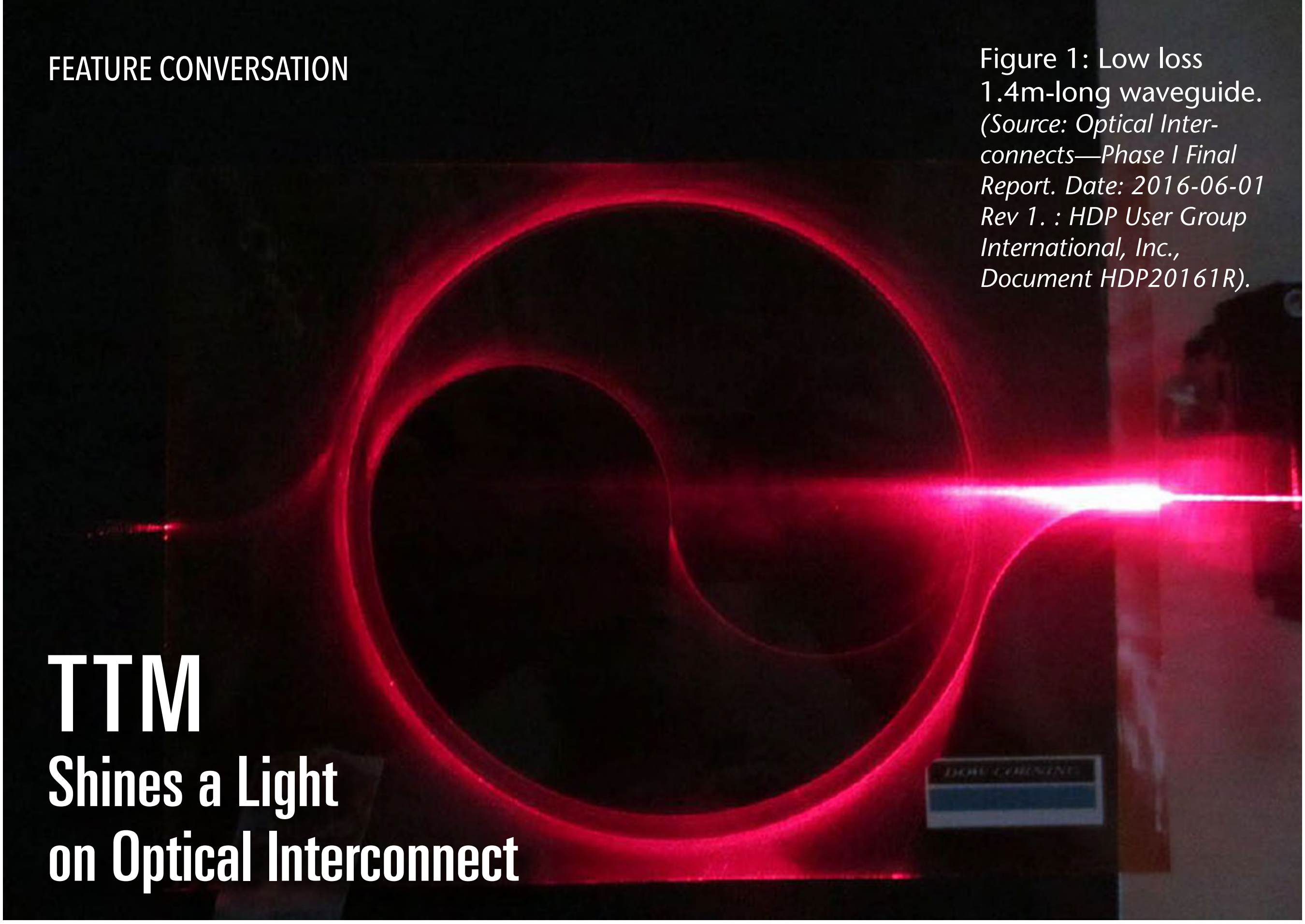


Figure 1: Low loss 1.4m-long waveguide. *(Source: Optical Interconnects—Phase I Final Report. Date: 2016-06-01 Rev 1. : HDP User Group International, Inc., Document HDP20161R).*

TTM
Shines a Light on Optical Interconnect

by I-Connect007

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, what that would mean for the PCB industry, and why he thinks there will be manufacturing production capability by 2020.

Barry Matties: Craig, for context, tell us a little bit about the optical side of TTM and what you guys are doing there.

Craig Davidson: Sure. We're engaged already with the optical groups of many large customers. As you probably know, there are optical products today that do not include onboard optical interconnect or inboard optical interconnect, but rather optical cables to the edge of the board. These include fiber connectors and transceivers embedded in connectors. TTM certainly supports networking companies with these kinds of products formally classified as optical.

What we're really taking about here is the future as we bring optical signals on board, onto the printed circuit board directly embedded in the board for optical packages, line cards or backplanes.

***Matties:** Yes.*

Davidson: The basic capability has been around for decades. I first got involved in it back in the year 2000 when there was a big push for onboard optical interconnect and just about every printed circuit board fabricator at the time was doing something around embedding fibers into boards. Many PCB fabricators have these kinds of processes. It's relatively simple to do but it's not a very happy solution.

You still have problems with 90° bends, for example, and the z-axis in the board, and you certainly have continuing difficulties associated with connectorizing the fibers. Also, importantly, is registration—making sure the fibers actually end up where they need to be. That's a very difficult task. So those types of problems haven›t really been solved for

a long time. The TTM team in Europe has been working on this for a long time now. And you interviewed Marika Immonen on our team back in 2015, I believe. TTM now has technology we can offer that will allow embedded waveguides in boards. This includes polymer waveguides either buried inside a board or built-up on the board surface and with in-plane or 90° connectors. We›re working jointly with several consortia and individual companies to demonstrate this technology.


Craig Davidson

So that's a brief history of where we have been and at least a little preview of what we can offer. TTM has a long experience of fabricating multimode waveguides for short-reach datacom applications. Now as silicon photonics at OEMs is pushing through, we are scaling technology to support their single-mode roadmaps. There we pursue both polymer- and glass-based waveguides. Polymers are very versatile, low cost and easy to fabricate, whereas glass provides low loss at the longer wavelengths and optical compliance with fibers. Single mode waveguides are looked at to provide complex routing between chips or to serve as "bridges" between sub-micron silicon waveguide and 9-micron fiber. In single mode, accuracy and registration both in waveguide fabrication and termination is critical.

***Matties:** And really the impetus behind this is the speed barrier, right?*

Davidson: Yes, it absolutely is. We're now in production with 25-gigabit backplanes, and by that I mean per channel, so it's some of the fastest boards out there these days. We know that companies are already working on product for the 50-gigabit node. The generation after that is also being developed now and will be around 100 gigabit per channel. I think it's those speeds that people are most focused on for these optical interconnects.

We know that even 25 gigabit is difficult to manufacture because of the tolerances required. The 50-gigabit node will be very difficult to manufacture, again because of the losses. Low-loss materials are required and the tolerances on the copper and dielectric geometries in all dimensions are going to be very demanding for even the 50 Gb. The consensus from our customers seems to be that with the 100-gigabit node we really will have to be thinking pretty hard about moving to optical interconnect onboard as more traditional PCB fabrication techniques may not be capable of the tolerances required.

***Matties:** Now, with regard to high-speed materials and the traditional coppers, haven't they broken barriers that have been somewhat surprising to the industry? Barriers that technologists had previously predicted would never be breached with copper?*

Davidson: Yes, I think that's true. I remember hearing "Oh, geez, we need flip-chip next year or we're out of business." Or in 2000, they said, "If we don't have embedded optical in a year or two, we're out of business." None of those things came to pass. It's remarkable how robust existing technology is and it's always so much easier to make incremental improvements to what exists than to implement a whole new type of technology.

This 100-Gb barrier might be a little bit different because it does not rely just on opinion regarding what future manufacturing technology will be able to deliver but on fundamental calculations of losses associated with current materials. Other factors may delay the requirement of embedded optical. That could be software solutions such as error correction or additional functionality such as on-board repeaters. But the physical solutions come with severe power and thermal dissipation requirements.

Nevertheless, embedded optical is a focus for us and our customers. In fact, we have manufacturing techniques now that we're ready to introduce into pilot and volume production. We want to be able to deliver optical interconnect at reasonable costs and at these kinds of performance levels. TTM's goal is to ensure we have the technology if it's needed and in that time frame.

***Matties:** Now, with regard to your technology, is this already being used in any practical, commercial application or is it all design and experiment at this point?*

Davidson: Well, we're past the experimental stage. We have a stable manufacturing process now. Of course, we continue development of new materials and the maturation of our manufacturing processes. We provide pilot-level quantities with good yield. The industry focus has been on proving out the overall technology with evaluations and demonstrators. We are engaged with many companies and consortia to do demonstrators assessing how optical interconnect technology could be used in package substrates, line cards and backplanes and measure the benefits.

TTM has built many demonstrators for companies—mostly through joint development activities either one-on-one, bilateral types of development, or through the many consortia of which we are members or with which we cooperate closely, for example PhoxTrot in Europe and AIM Photonics here in the U.S. They have designed demonstrators to determine how best to employ these tools and determine design parameters. We're building functional demonstrators for companies that include routers, switches, other types of networking devices, and storage applications. Cloud storage arrays have different requirements and configurations than a network line card, as an example.

***Matties:** Now, with regard to manufacturing and your techniques, you mentioned that TTM has an optical line. Is this manufacturing equipment that you've partnered with suppliers to produce or is this internal development to create the manufacturing process?*

Davidson: We're using existing PCB fabrication technologies including material deposition, imaging, patterning, etc. I don't think at this point we have to design or develop any unique tools but rather utilize our innovative approaches to fabrication and incorporate light transmission materials—for example, polymer waveguides. These tend to be photoactive materials. We can deposit and define using typical phototools with high precision. But it's something that the industry understands and is recognized by our customers which reduces risk and raises confidence. We have already done up to two embedded optical layers on a 20-layer backplane as one of the demonstrators. This is a demonstration of real product containing all regular copper layers and functions and it is quite a complex product to build.

***Matties:** That's quite the undertaking.*

Davidson: Yes, it is. It's quite exciting and not a revolution from a technology point of view. We can deliver the tolerances required and continue to evaluate some of the newer optical materials that are available to us now. We've been evaluating the polymer waveguide materials that are offered by different companies. And now the new glass waveguide materials are also

> **"We are already using these embedded glass waveguides for the higher-performance applications."**

being offered. We are already using these embedded glass waveguides for the higher-performance applications. Quite interesting.

***Matties:** I bet. For other fabricators, I assume you are licensing this process; when they embrace the process, it doesn't sound like a lot of capital investment, but more process knowledge and training.*

Davidson: Yes. I'd say that is mostly true. We know how to set up a manufacturing line to do this. Obviously, because of the geometries and materials, cleanliness is important. So, we're just making sure that for a volume line, we've got sufficient cleanliness at the appropriate process step. But yes, we know how to build a volume line to do this today. We're pretty confident.

Now we're waiting for the business. We remain close to our customers. The industry is now looking at different ways to employ embedded optical and you probably also know that companies have different approaches to their system architecture. Some companies make very heavy use of big backplanes; others not so much. Some use smaller mid-planes. Some use harnesses instead of backplanes. They all have slightly different architectures and they are working the benefits of optical interconnect into their designs. The result will be, I think, different solutions and different product. We are gaining a lot of experience with these different approaches and solutions.

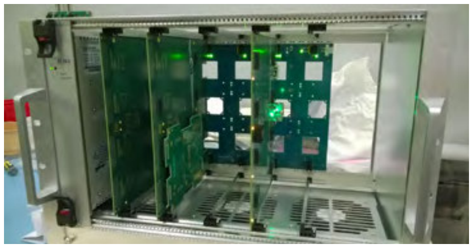


Figure 2: System enclosure with joint HDP OE2/PhoxTrot ecosystem demonstrator.

We're waiting for a little more maturity in the industry to see how they're going to do this. We've been quite open with our customers. As soon as you have a design, even a pre-production type of design, we're ready to go work with you on it and make sure that we can put it in play. Right now, most of the industry is focused on test vehicles and demonstrators but they are quite sophisticated, by the way. They are functional and almost products unto themselves.

***Matties:* When do you see this becoming more mainstream, where it's market-accepted and product-proven in the real world? How long a time frame?**

Davidson: Well, that's a really good question. We're asked internally and externally all the time.

***Matties:* I bet you are [laughs].**

Davidson: Our forecast comes from our customers and potential customers. But we are focused on the 100-gigabit per channel node, which is predicted to be in full production sometime in 2020–2022. There is no commercial product yet. As far as the process technology is concerned, we're expecting that in the year 2020 we may need to be in production. We are planning the expansion of our pilot lines and low volume lines now to understand the real business case for this. We want to be ready to go when companies have real products they want to put into production.

***Matties:* Primarily this is tied to the server farms, the big server markets, communications—there's a real need for speed there, of course. Do you see this reaching, say, the automotive industry with the need for speed around autonomous vehicles?**

Davidson: I think it's certainly going to penetrate the infrastructure type of product—the big switches and hubs and other infrastructure product that's going to be needed to support autonomous driving. True autonomous driving probably isn't going to happen until the 5G node is fully deployed. Things like latency in our Internet connections today needs to be quite a bit better for full autonomous. I don't see optical interconnect going into a car first. I see it mostly right now penetrating the types of infrastructure products that we already produce. It'll take a little while longer before anything needs to be done inside a car—at least as to high speed requirements. As you know, we're also one of the largest automotive suppliers in the industry with a strong share in safety critical applications. So, we're very familiar with the qualification requirements and reliability requirements of the auto industry. The time it takes to qualify new materials and processes is quite extensive in the auto industry. I don't see them adopting this as a leader; maybe a fast follower as needed.

Having said that, the automotive guys are subject to some things today that they were not before. They are buying commercial semiconductors that are fast and in big, complicated high IO packages. I see them advancing along the density curve—from where they were

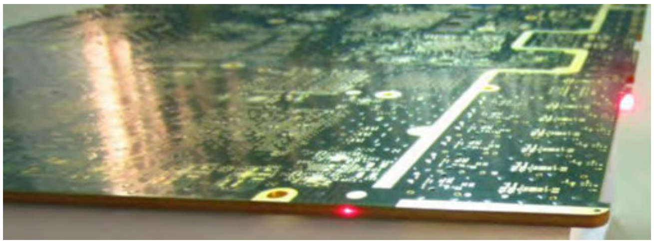


Figure 3: 20-layer optical line card with embedded polymer waveguides (20L+1Opt).

yesterday and where they are today—faster than most other industries have. They have to buy the latest chips and those chips are complicated and dense. We see them adopting HDI faster probably than most other industries have. Maybe the same will occur with optical interconnect once it is available.

***Matties:** I would think that you're going see that with companies like Nissan, which is one that comes to mind that's really driving automotive technology and electronics. I would think that these guys would be knocking on your door sooner rather than later just because it seems that the electronics is the advantage that they have in every vehicle, aside from the standard seat and steering wheel luxuries. It's really the differentiator.*

Davidson: Yeah. They really do need speed in the Internet connection and the information back-and-forth with the car, and that's all going to be done wirelessly, of course.

***Matties:** This is great. Does anyone else have any questions for Craig?*

***Andy Shaughnessy:** From what I know about optics, it seems like it's not perfect, but it seems like a whole lot better method for transmitting a signal than copper. From what I understand, there are almost no resonance problems, a lot of the EMC and signal integrity problems go away, and you can make optics 10 times the density of HDI copper. If we could ever get it standardized, designers are really praying for it.*

Davidson: Yes, I think you're right. The benefits are there, for sure, and I think there's a big flywheel that has to be spun up in terms of understanding how to use this technology, having PCB designers who are familiar enough with it that can actually integrate electrical and optical on the same board. These kinds of skills aren't all that prevalent out there. And something we are also considering as we ramp this technology and evaluate new materials is looking at reliability. TTM already is a high-reliability supplier including aerospace and defense and the safety-critical automotive. Even in our telecom customers, when we build a backplane for them, they're worried about the reliability of that backplane. Line cards can more easily be swapped out if something goes wrong, but a backplane…no. Just as in today's designs, the designers' understanding of this technology will also be important to reliability.

As of now, we haven't seen reliability issues. Most of the early work has been done to prove out the technology and assess its capabilities. Now TTM is looking at some of the reliability aspects, including the materials and the manufacturing techniques. We're fairly confident about it. The industry is still not able to offer it in volume as a solution including second sourcing and having designers who are familiar with the manufacturing techniques and the design space to be able to effectively use it.

***Patty Goldman:** I'm wondering if most of this development is being done here in North America and what sort of interest there is in foreign markets like in Europe and in China?*

Davidson: TTM is a global corporation and the Corporate Technology group within TTM is also global. We have people located around the world including Asia, Europe, and North America. This particular development activity reflects the organization with project members from all geographical locations. We fabricate boards with embedded optical interconnect with participation from our global technology team and involving many of our sites around the world. This also represents a broadening of our internal experience base and gives more confidence to our customers.

The customer base we are working with today in optical interconnect product are also truly international and located again in Asia, Europe, and North America—everywhere that you see companies engaged in networking, telecom, and storage systems.

Steven Las Marias: ***Craig, with the proliferation of optical boards, do you think it will require a different set of manufacturing or assembly expertise or techniques?***

Davidson: Yes, I do. The early work in this space was subject to many issues, not the least of which was registration and making sure you know the precise location of the fiber. This has a major impact on assembly. You probably know that the connectors have to be lined up with the waveguides requiring a lot of precision and even active positioning perhaps. That is, putting an optical signal through the board to optimize component and connector positioning during the assembly operation. In some of the higher speed optical, we're talking about a few microns of registration accuracy required. That's quite a change for most of the assembly operations. Our embedded wave guides, as opposed to fibers, reduce this overall problem, but new approaches to assembly are required. For the consortia work in which we have participated parts were sent to the connector companies because they have the tools to do this type of connector alignment and assembly. That's obviously not a very happy solution for volume manufacturing.

So the industry needs appropriate volume assembly solutions. It's also very dependent on the type of connectors you're going to be using and the board technology. TTM is heavily involved with the connector companies. I didn't really point that out before, but in all of the demonstrators and prototypes, we're heavily involved with all the connector companies, and are aware of their new connector technologies and connector designs coming to meet this requirement. It is a challenge to put these connectors on and make sure that they're within a few microns of where they need to be. If you could do that without active alignment by using new assembly approaches that would be interesting.

It's also an area that TTM is looking at as we also have assembly capabilities in-house.

Matties: ***I think there's a whole list of new connectors that have to be developed to be compatible with this technology as well. It's not just items off the shelf. They have to design and develop new technology for this specifically, right?***

Davidson: Yes, there are connectors now like today's cable connection; you just plug it into the receptors on the board. But as we begin to integrate optics into the board, we clearly need new sets of connectors. The connector companies are developing them and we are evaluating them. It's also true that in the evaluations the connectors are a significant part of the losses in the system. Connectors represent a discontinuity—electrical or optical—so I guess you'd be surprised if they weren't also a loss problem in optical systems as well. We're quite happy with the performance of the embedded optical waveguides we have in our boards, but we know that there needs to be improvements in the connectors and at that interface to keep loss at a minimum. So, yes, a very important part.

These technologies play together in a very systems-oriented solution, I think, including design which also plays a prominent role. Our ability to embed waveguides in the right configurations is a major part of the solution. When you start thinking about it all, all the components must be ready for a manufacturing production capability by 2020. There's not much time to put it all in place and prove it out and make sure it's integrated and with a supply chain that's ready to go.

Matties: ***It's a large undertaking for sure, and I know when we first started talking about it with Marika in 2015, TTM was thinking three to four years. To me that seemed like a long time, but when you start looking at the entire infrastructure that needs to be developed and supported, it's not long at all. It goes by very fast.***

Davidson: Yeah, not long at all. In fact, it's quite exciting and very interesting for sure.

Matties: ***I bet.***

Davidson: In the 1980s and '90s, companies were more vertically integrated. They had their own board shop, wafer fab, and did all the assembly on their own designs. We could put together a program that was very vertically integrated and make it work on a short time scale. Today, of course, not so much. It's quite difficult to put together the integrated solutions necessary. Global companies like TTM that have many of the required capabilities and a culture of internal cooperation are in a good position to help fill those gaps.

Figure 4: PhoxDem09.04MPX – 18L+2 opt embedded WG layers.

***Matties:** Yes. I would think with the global footprint and the supply chain it's very difficult. Is there anything that we haven't talked about that we should be sharing with the industry?*

Davidson: Oh, let's see. Well, I guess the only comment I have is that many companies don't understand what it takes to qualify new materials and processes. That's very true outside of the optics space, for example with high-speed materials. This has been an issue now with the industry for the last decade or so. So many new materials are being introduced and it's difficult to characterize them fully for all the variations of PCB configurations including straight up lam, multi-lamination, different types of via constructs, different copper weights and copper profiles, different glass styles and for different applications. It is really quite a challenge. Companies sometimes forget the work involved and the risk they take when introducing new materials to their products. TTM also has a very extensive materials program to look at all these aspects of performance and provide experience and data to customers.

Having said that, the proliferation of materials gives us many now to choose from when before there may really have been only one or two in key performance categories.

***Matties:** We've heard about the material process, the approval process and how lengthy it can be—a multi-year process in some cases. Do you see ways of streamlining this process that the industry should be considering?*

Davidson: Yes, and we do participate in leveraged activities where we can to help with this work. TTM, for example, is a member of HDPUG (the High-Density Packaging Users Group) and we are a big supporter of HDPUG. Through HDPUG, we can evaluate many new materials. If you go through the literature, HDPUG periodically publishes results. They have done a lot of really good work in terms of lead-free compatibility and CAF performance over the years with the newer high-speed materials. We take advantage by working with these consortia and leveraged activities whenever possible, so that helps.

Some companies understand how difficult this is and have very aggressive and rigorous materials qualification programs.

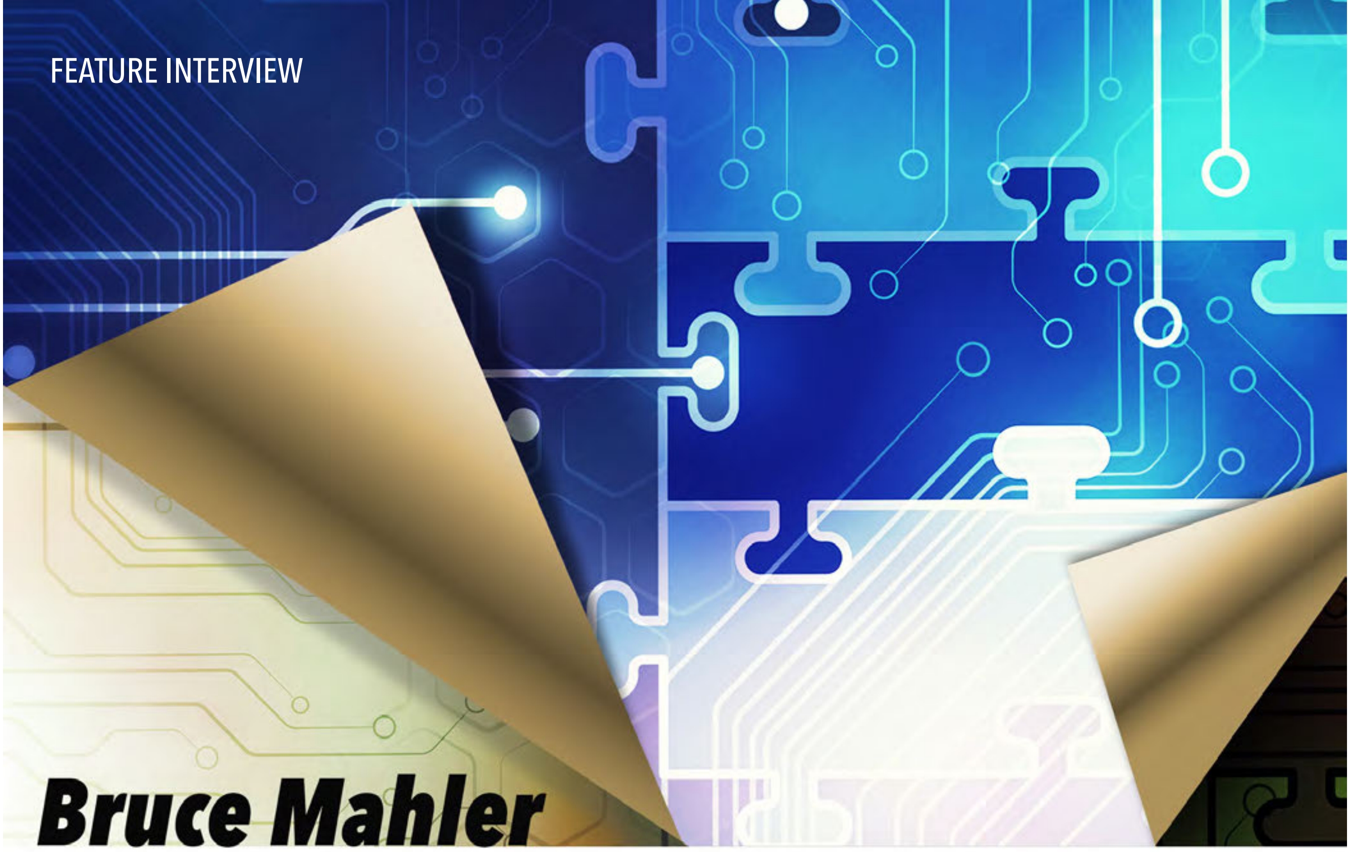
That's certainly true of the automotive customers. Many have internally qualified—with their suppliers' help—their own materials list. But there are many customers that really don't have that expertise internally. But they can take advantage of our extensive materials test database and process expertise. Obviously, today, there are designers that have never been in a printed circuit board fabrication facility. They just go through a catalog, pick a material that seems right and use it. Many times, that's not the right way to go.

***Shaughnessy:** That's most of my readers, Craig. I think half of my designer readers have never been in a board shop, and then for the few that have it's been 25 years.*

Davidson: Yeah. I totally get it. We have outreach programs within TTM, run by our applications engineering team that's out in the field all the time. They are doing lunch and learns and PCB-101 fabrication seminars for companies and otherwise lending fabrication expertise.

***Matties:** Well, Craig, we certainly appreciate your time today and we know you're a busy man and we thank you for your insight for sure.*

Davidson: Sure, no problem. I enjoyed it. Thank you. **PCBDESIGN**



Bruce Mahler

Discusses Ohmega's Resistive Material Technology

by Andy Shaughnessy

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.

***Andy Shaughnessy:** Bruce, why don't you start off by giving us a brief background on Ohmega Technologies.*

Bruce Mahler: Ohmega Technologies manufactures a thin-film resistive material, which is a nickel phosphorous alloy plated onto copper foil. That resistive foil, called OhmegaPly RCM, is laminated to a dielectric like regular copper foil and is then subtractively processed using standard PCB print and etch, to create resistive elements that are either embedded within a multilayer printed circuit board or onto the surface of a printed circuit board. We've been doing this for more than 40 years now, and we're surprised with the variety of applications that use our technology. Every year it seems that there are new applications, new ways to use the resistive film. So, it's like a constant renewal of the technology in new opportunities, of new growth of the use of embedded resistors within printed circuit boards.

***Shaughnessy:** What are the primary markets that these boards wind up in?*

Mahler: Good question. One of the primary markets is A&D (aerospace & defense) which we have been supplying our products to for decades. It's mostly used in radar systems, control circuits, and in critical operating systems where absolute performance and reliability are essential. The resistive material cannot be affected by temperature extremes, high G-force, vibration, magnetic or cosmic radiation and those kinds of things.

The other big market is sensor technologies. We supply our product to the MEMS microphone manufacturers. If you have a cellphone, you probably have OhmegaPly within that cellphone. We're used in the MEMS microphone of cellphones as part of an RC filter to improve the sound fidelity of the microphones; we've been doing that for many years. There's also a growing area of applications and use in sensor

technologies: not just MEMS microphones but other MEMS devices and technologies.

The third area of use where we see growing opportunities are in heater designs. Heater elements are used for things like semi-active laser activation of smart munitions or embedded resistors as heater elements in a printed circuit board to maintain surface components at optimum temperatures for optimum operation, whether that's in deep-space applications or even down to earth in medical diagnostic type applications. OhmegaPly has also been used as an internal heater in burn-in boards to allow for IC burn-in without the need of a temperature chamber.

Bruce Mahler

Shaughnessy: *Does this work at RF speeds?*

Mahler: Yes, absolutely. In fact, many of our applications in the gigahertz range are mostly using our product as a replacement of chip resistors in power dividers. In that case, we're using low dielectric constant materials like traditional PTFE materials that Rogers, Arlon and Taconic supply. We see a growing trend, both in higher speed and higher performance, as well as in very, very fine-line modules, chip carrier and those kinds of areas of applications to use lower dielectric constant, low-loss dielectrics from Rogers and Arlon and Taconic as well as materials from companies like Panasonic and Isola.

Because the resistor material is essentially inductor-free; we remove a lot of the parasitics coming off a board to make it very attractive at higher frequencies of operations. Line termination in very high-density IO is also an attractive use of the technology by a lot of our end-users, especially in the next generation of memory and in chip carriers and IC carrier modules. In these cases, we~~,~~ are looking at extremely fine line circuits, resistors built within traces of 50 micron, 40 micron, and even narrower.

We're talking about extremely small resistors, and the ability to image and etch those accurately is very critical, so we see that the kind of copper being used is getting thinner, and now we're offering a 12-micron along with our standard 18-micron copper. We're also working with a five micron, and ultimately a three-micron copper on a peelable copper carrier. In addition, we're starting to supply lower-profile coppers as well so you have not only better performance at the high-frequency gigahertz range for microwave type applications, but the lower-profile copper also adds in the accuracy with the imaging and etching process of line traces, which ultimately mean more accurate resistive elements as well.

For that reason, we see a growing trend in our industry for thinner coppers, lower-profile coppers, new dielectric materials with lower loss and lower dielectric constants and capable at operating effectively at higher frequency.

Shaughnessy: *What do you see going on in advanced materials that's really caught your eye?*

Mahler: In advanced materials, our area of focus is the development of products which are more accurate, on thinner and very, very low-profile coppers with good adhesion, and also ultimately with tighter resistive value tolerances. I think that when it comes to the dielectric types that we're seeing, as I mentioned before, the development of low-loss materials; it's not just PTFEs but also a lot of the other polymers that are being developed today.

We all have exacting standards. You want something that is halogen-free. You want things that can handle lead-free assembly. You want things that can environmentally meet all compliances, REACH and RoHS and all the rest. Really what you're looking at is material that operates very effectively at the higher frequencies; data rates are increasing, and ICs are going a lot faster, which means more of a need for our product for things like termination.

In addition, see more and more applications for, again, heater elements. Our product as a resistor can heat up and because of that you want to have dielectric type materials that have good thermal conductivity. Along with the lower di-

electric constants you want materials that have good thermal characteristics and can withstand high temperatures, high operating temperatures, but also can thermally conduct heat away from resistive elements or heater elements in particular, and place it where they want to place it on a board.

***Shaughnessy:** Your products have to play nice, basically, with all these various dielectrics.*

Mahler: Yes, we're independent of the dielectric. We make the resistive foil. We sell the product to the laminators out there who bond it to their dielectric, or we work with many of them on a subcontract basis. Our focus is making the best resistive product we can possibly make and offer to the industry, and essentially let those laminators, the experts in dielectric materials, develop the kind of polymers and the kind of substrates that the industry is asking for and then working hand-in-hand with the laminators offer a solution to the end user that combines the best of both worlds—the best resistive material coupled with the optimum dielectric material. That's what we're doing.

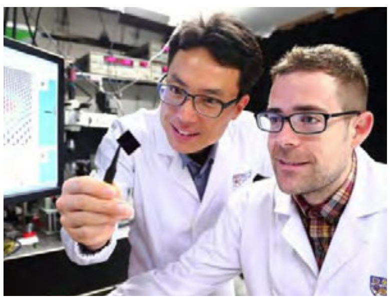
Again, 40 years we've been doing this and what's exciting is we see the future as being brighter than ever—the Internet of Things, new sensor technology, automotive applications, the avionic applications, growth of sensor technologies, at-home devices, wearable devices and so on. We're involved with so many things that are so exciting, and we just can't wait to see how things develop over the next few years.

***Shaughnessy:** Congratulations. Well, Bruce, that's very exciting and I wish you the best. Thanks for speaking with me.*

Mahler: Thanks, Andy. PCBDESIGN

Ultra-Thin Multilayer Film for Next-Generation Data Storage and Processing

A team of scientists led by Associate Professor Yang Hyunsoo from the National University of Singapore's (NUS) Faculty of Engineering has invented a novel ultra-thin multilayer film which could harness the properties of tiny magnetic whirls, known as skyrmions, as information carriers for storing and processing data on magnetic media.



The nano-sized thin film, which was developed in collaboration with researchers from Brookhaven National Laboratory, Stony Brook University, and Louisiana State University, is a critical step towards the design of data storage devices that use less power and work faster than existing memory technologies.

The digital transformation has resulted in ever-increasing demands for better processing and storing of large amounts of data, as well as improvements in hard drive technology. Since their discovery in magnetic materials in 2009, skyrmions, which are tiny swirling magnetic textures only a few nanometres in size, have been extensively studied as possible information carriers in next-generation data storage and logic devices.

The NUS team, which also comprises Dr. Shawn Pollard and Yu Jiawei from the NUS Department of Electrical and Computer Engineering, found that a large DMI could be maintained in multilayer films composed of cobalt and palladium, and this is large enough to stabilise skyrmion spin textures.

In order to image the magnetic structure of these films, the NUS researchers, in collaboration with Brookhaven National Laboratory in the United States, employed Lorentz transmission electron microscopy (L-TEM). L-TEM has the ability to image magnetic structures below 10 nanometres, but it has not been used to observe skyrmions in multilayer geometries previously as it was predicted to exhibit zero signal.

Steve Robinson
Discusses APCT's Tenfold Expansion

by Andy Shaughnessy

Steve Robinson, CEO of APCT, a PCB fabricator in Silicon Valley, has lead 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.

Andy Shaughnessy: Steve, it's good to finally meet you and put a face to the name. Why don't you start off and give us some background about APCT?

Steve Robinson: I've spent 46 years in the printed circuit board industry. In 2008, I left Merix Corporation as their Executive VP of Global Operations and was looking for the opportunity to establish a company with a high level of service and technology and a little more flexibility. I acquired APCT in 2008. At the time of the acquisition, it was a low-technology facility in Santa Clara, California, producing two- and four-layer boards. Annual revenue was at $4 million and only four customers. It really wasn't the customer list or the product mix that attracted me, but the layout of the facility. The industry was changing and evolving in North America and I loved the idea of having the opportunity to grow into a facility and create the environment that I had always envisioned the industry needed.

We spent the last eight and a half years enhancing the facility and growing the customer base. We have invested over $9 million in equipment and facility renovations and, today, we have transformed to an advanced technology, HDI-focused operation. This year, we'll do about $39 million in revenue. We have four hundred active customers and our engineering and core competency is building solutions in the advanced technology segment, especially in HDI, where industry designers start to struggle

with manufacturability and with a program they can launch forward. That's really where APCT sits today. We now have two facilities: one in Santa Clara, the other in Wallingford, Connecticut. We have 188 employees, 80,000 square feet, and we service every market in the industry.

Shaughnessy: ***So you had a tenfold increase in revenue? We don't see that very often.***

Robinson: We've been fortunate. We've had eight years in a row of double-digit growth. In that period, our largest growth year was 38% and our smallest was 17%. We've been very consistent in achieving our goals and I'm certainly proud of attaining these numbers during such challenging times. I think if you develop a model that resonates with the needs of any business you're going to attract new customers and new opportunities. I think we have a model that is sustainable and still valued in the industry.

Shaughnessy: ***You acquired a board shop in 2008? That was some great timing!***

Robinson: In 2008 to 2009, my wife and all my friends said, "What have you done?!" The industry had collapsed and yet we continued to invest a significant amount of money in resources and equipment. So after a $2 million loss over the first two years, we knew we had to remain positive and keep investing. The top line growth of the business didn't sustain the investments we were making, but it turned out to build a foundation that fortified our current success and growth. We believed in our model and felt confident that the industry would turn the corner, which it finally did.

Shaughnessy: ***Do you have an engineering background?***

Robinson: No, I don't. In 1971, I was a swing shift plating line operator when I got out of high school. I'd go work second shift in the plating area, so I spent my first seven years in process and manufacturing and then I spent my next 11 in sales. My mentor in the industry told me I would never be a success in managing a business if I didn't have an intimate knowledge of both sides of the business, manufacturing and customer interfacing. It was very important to him that I become an expert at both.

My core competency is business management and team building, but thanks to my early mentoring, I learned how to run a business the right way. And today it's all about the people. It's focusing on the customer; it's listening to their needs and building a solution. In any business, the goal is to provide value that people are willing to pay for. That's the key thing. You've got to provide a service that creates value. APCT's strength is our design for manufacturability, our detailed engineering and customer support, and our technical capabilities. We can provide the fastest lead times in the world, which is always a nice niche to have, but it's really our people, our attention to detail and our willingness to push the envelope that resonates with our customers.

Shaughnessy: ***You said you focus on advanced technology. What would you say is your sweet spot, so to speak?***

Robinson: Our sweet spot is multiple lam cycle HDI work; stacked vias, 50-micron technology, and build-up technology. That's really where our core growth has been. Two years ago, that was 5% of our business; today it's 80% of our business and growing. Design needs are changing, component sets are evolving and designers in the industry are working hard to stay ahead of the curve. Our focus is to support those efforts, especially in the markets we've targeted.

Shaughnessy: ***That goes with what my designer readers are telling me, that the advanced high-speed arena is where all their problems lie. Everybody has signal integrity problems now and they need to have a partner who understands it at the fabrication level. That sounds like that's where you fit in.***

Robinson: We do, and I think we see designs now that, in some cases, just need guidance. So with the early involvement that we get with our DFM and pre-quote engineering teams, we're working with design groups in very early stages, enabling them to launch successfully. There is

a lot of value in the model of an engineering and NPI facility. Now, the natural progression is to assist our customers in launching their volume orders offshore. Because of my team's experience, we have the ability to design for success in lower cost regions. In many cases now, they're coming to us because it's a recipe transfer problem the customer is facing. They ultimately are going to need to go to a cost-effective solution, but they can't transfer the same recipe we build in NPI. We can build anything, but they are never going to get it built offshore successfully, so we're now focusing a lot more resources in developing NPI and DFM feedback that allows them to be successful. We're engineering for their ultimate solution, not just launching an NPI program for them. This model has been very attractive to a lot of Tier Ones. They have leveraged our speed in the NPI build, allowing them to get to market quicker and they are trusting us in the recipe transfer, in order to take advantage of pricing for product produced in low-cost regions as well. That's a big part of our growth, especially over the last two years.

Shaughnessy: ***What do you see over the next five years or so? Are you planning to expand into any new markets?***

Robinson: We will continue to focus on what our customers are asking for. Our customers want our engineering expertise, and they want our commitment to a high level of service. We have a very responsive inside sales team as well. We get quotes back to customers in a few hours. We strive to be very effective with our communication, our follow-up, and we give them very honest feedback and commitments as we go forward. That said, we have customers now asking us to look at expanding some of our technologies. Flex and rigid-flex technology is something that we're looking at right now. If we do add that capability, we will not be adding to our existing footprint, but perhaps through another acquisition. We acquired the Connecticut operation in April of 2016, which added a substantial manufacturing site for us on the East Coast, where we now have additional resources and capacity to support those regional customers. We have a significant level of revenue coming from the East Coast and our new facility out there is doing a tremendous job supporting that growing demand.

Shaughnessy: ***Right now, you don't do any flex?***

Robinson: We are currently focused only on rigid boards. We are very dedicated to what we do. However, flex and rigid-flex is a growth market in North America, so it is something we are considering. There could be other acquisitions that, logistically, might make sense for us regionally. But right now, it's about being more efficient and continuing to focus on the technology that we're seeing currently. We're not seeing a lot of new and emerging technologies, but thinner, faster, and smaller. That's where all the OEMs are driving us, so it's low loss/high speed materials with smaller features, smaller holes and just finer detail. As you invest in those capabilities they become significant, so you have to be very certain of what you're doing.

Shaughnessy: ***It's funny. We see some designers who automatically go to HDI and then sometimes***

the board shop tells them, "You don't really need to do it for this," because designers over-constrain their designs.

Robinson: We see that as well. A lot of them go to HDI and some of them we are able to back off and still achieve their design needs. Others that don't go to it and need to go to it are trying to continue to reduce the pad sizes, but they just can't get there. But working with designers, they're evolving, and they're learning. It's new for them as well and they're under a lot of pressure to meet timelines.

We provide a value that allows designers to be successful and through that, we develop a relationship and a trust. Our sales and marketing campaign is all about passion, commitment and trust. It's unique. We're a technology producer and in fact, may be the fastest technology producer in the world, but we don't market that. We market our passion, our commitment, and our trust, because it's the trust of a customer that we think has sustained our growth.

If you can develop trust, you can develop loyalty. So we become very loyal to our customer and, in turn, the customer becomes very loyal to us. That is, I think, the core of a successful business and I know it's the core of our business, our success and our growth. It's the trust we've earned over time with our customer base and that comes with an investment that we have to continue. We have to invest in people, we have to invest in technology, we have to invest in equipment, and we have to invest in capacity. We have to continue on that path, because our demand continues to grow and grow.

But we're still a size that allows us to be flexible and nimble, and tighten the belt whenever necessary in this business, because our forecasting is limited. In fact, there is none. Our industry has always been that way. That's why we spend such a significant amount per year on marketing, especially in the social media space. It's where your recognition is. We just want to continue to look for new opportunities. We don't need more business just to fill factories. My factories are full.

We're not looking for POs and transactions. We're looking for new partnerships; we're looking for long-term commitments in which we can build and sustain those partnerships. We're looking for new relationships that make sense for them and make sense for us…a good fit if you will. That's a fun way to do business. We're fortunate to be in that position and we've earned that position through our effort and our success over the last few years.

Shaughnessy: That's a good spot to be in. Is there anything else you want to add?

Robinson: I think it's "Say what you do, do what you say." Be honest; treat your customers with respect, the small ones and the big ones. I have multi-million dollar customers and I have thousand-dollar customers. We treat all of them in the same way in my company, because our goal is to have all customers feel important and trust that they will be treated accordingly. But business is good, Andy, and I think we'll continue to grow as long as we stay focused on our task.

Shaughnessy: Thanks for talking with us today, Steve.

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

Damping Gives a Faster Switch

The optimal material properties required for magnetic memories to have ultra-low power consumption are identified using simulations performed by researchers at A*STAR.

Most RAM devices store data electrically in an integrated circuit. However, storing information magnetically could enable even faster operation. Switching the magnetization, and thus changing the memory from one binary state to another, can be achieved by just applying a magnetic field, but this requires a lot of power.

BingJin Chen and Guchang Han from the A*STAR Data Storage Institute use micromagnetic simulations to investigate electric-field assisted magnetization switching in magnetic random access memories.

2017 Programs

April 5
Wisdom Wednesday — **Webinar**
Reliability Fundamentals: Failure Mechanisms and Success
Mike Carano, RBP Chemical Technology
IPC Members Only

April 25–27
The 14th Electronic Circuits World Convention — **Conference**
KINTEX, Goyang City, S. Korea

April 26–27
IPC Reliability Forum: Manufacturing High-Performance Products — **Conference**
Chicago, IL, USA

May 1–3
IMPACT Washington D.C. 2017 — **Meeting**
Washington, D.C., USA

May 10
Wisdom Wednesday — **Webinar**
IPC Members Only

May 16
IPC Committee Meetings — **Meeting**
Nuremberg, Germany

June
IPC Summer Committee Meetings — **Meeting**
Minneapolis, MN, USA

June 7
Wisdom Wednesday — **Webinar**
IPC Members Only

June 27–28
IPC Reliability Forum: Emerging Technologies — **Conference**
Dusseldorf, Germany

July 26–27
Technical Education — **Workshop**
Chicago, IL, USA

September 17–21
IPC Fall Committee Meetings — **Meeting**
Held in conjunction with SMTA International
Rosemont, IL, USA

October
IPC WHMA Cable and Wire Harness Technical Conference — **Conference**
Paris, France

October
IPC Technical Education — **Workshop**
Paris, France

October
IPC Technical Education — **Workshop**
Minneapolis, MN, USA

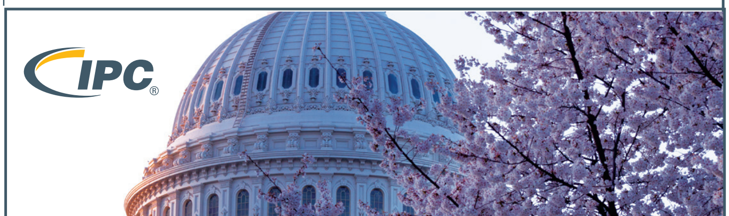
October 17–19
IPC Flexible Circuits-HDI Forum Tutorials and Technical Conference — **Conference**
Minneapolis, MN, USA

November
IMPACT Europe — **Meeting**
Brussels, Belgium

November 8
IPC Technical Education — **Workshop**
Raleigh, NC, USA

November 14
IPC Committee Meetings — **Meeting**
Munich, Germany

December 6–8
HKPCA International Printed Circuit & APEX South China Fair — **Conference and Exhibition**
Shenzhen, China



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Woven Glass Weave Effect: Electrical Concerns and Remedies

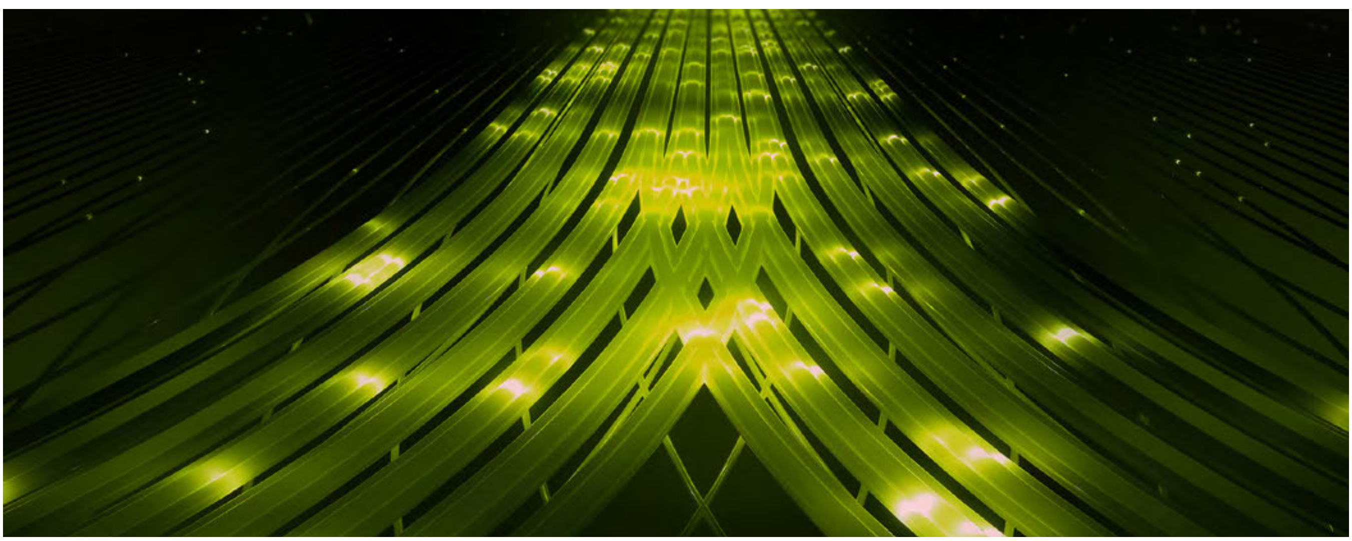
by John Coonrod
ROGERS CORPORATION

The idea of glass weave effect has been around for many years, and it is a topic that is somewhat controversial. In theory, the glass weave effect is a concern that the structure of the glass fabric can have a negative influence on high-frequency or high-speed digital circuit performance.

Most woven glass fabric used to improve mechanical properties of laminates has areas of glass bundles and open areas between the bundles. The glass bundles' dielectric constant (Dk) is typically about 6 and the areas between the bundles can have a Dk of around 3, depending on the resin system used to make the laminate. One concern for the glass weave effect is that if a critical circuit conductor is perfectly aligned to the pattern of bundles and open areas, the conductor will experience different Dk in small isolated areas. It is possible at very high frequencies or extremely high speed digital rates, that these isolated Dk differences could have an influence on the circuit performance.

One example of the glass weave effect: A microstrip transmission line circuit (two copper-layer circuit) uses a laminate with a Dk of 3.0. At 77 GHz, the ¼ wavelength will be about 0.024" and the 1/8 wavelength approximately 0.012". Theoretically, it is known that when an electromagnetic wave is propagating in a medium and encounters an anomaly that is ¼ wavelength or larger, the wave can be disturbed and possible resonances can occur. Additionally, real-world experience has shown that anomalies in the medium which are ¼ wavelength can cause wave propagation issues. If a laminate has a glass style with openings or bundle sizes which are 1/8 wavelength or larger, the discrete Dk anomalies of the glass bundles and open areas could cause circuit performance issues. Many different glass styles are used in the industry, and several glass styles have dimensions of 0.012" (1/8 wavelength at 77 GHz) or larger.

If the laminate is using two or more layers of woven-glass fiber, this may lessen the concern for glass weave effect in this example. When two layers of glass fabric are used to make the laminate, the odds of the bundles or open areas aligning is very unlikely. This means the discrete Dk anomalies due to the glass bundle and open areas will be greatly lessened and the impact on the wave could be minimal or insignificant.



There are other concerns with glass weave effect. To keep the explanation simple, it will be assumed that the laminate has one glass weave layer and that the circuit is a simple microstrip transmission line. Glass weave effect is often a concern where PCBs are used in large volume and potentially causing a circuit-to-circuit performance difference. A basic way to conceptualize the issue is to assume that most circuits will have a critical conductor randomly aligned to the glass weave pattern and the wave associated with that conductor is experiencing an averaging effect of the glass bundles and open areas. Then, in perhaps one circuit out of 100, the critical conductor is aligned perfectly, directly on top of an area of glass bundles and the wave will experience a higher Dk than the previously mentioned circuits. The higher Dk brings multiple effects: The impedance can be lower, the phase angle shifted, and the wave velocity slowed, all of which can impact the circuit performance.

A different concern for glass weave effect is the issue of circuits which have coupled features or use differential pair technology. When a pair of conductors in a circuit design has a well-defined relationship, each conductor must have the same wave propagation medium. If one conductor of the pair has a different medium, the coupled pair will not perform as expected by the designer. In RF applications, coupled conductors are used in filter and directional coupler designs. In high-speed digital application, coupled conductors are used in differential pair designs. For RF applications, if one conductor experiences a different Dk than its pair, the phase angle between the pairs will not be as designed and a shift in performance can occur. The high-speed digital application often has timing issues where the signals from each conductor of the pair will need to arrive at a point in the circuit at the same time. When the signals arrive at different times, that is knows as skew, which may be due to glass weave effect slowing the wave velocity of one conductor more than the other. Skew can be very problematic with very high-speed digital circuitry.

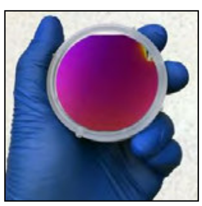
Many laminates formulated for high-frequency applications avoid issues with glass weave effect by utilizing a filled resin system. In that case, the open areas between the glass bundles do not have an abrupt difference in Dk from the glass bundles, as is the case with an unfilled resin system. The filler is typically a different Dk value than the resin system, which is also different than the glass bundles. The added filler helps to average the Dk differences in the isolated areas, and there is less of a discrete Dk difference between the glass bundles and open areas. Finally, some high-frequency laminates have no woven glass fabric; these materials are often used at millimeter-wave frequencies.

Don't forget that it is always a good idea to contact your materials supplier if you have questions about glass weave effect. **PCBDESIGN**

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

Low-Cost 'Solar Absorber' Promising for Future Power Plants

Researchers have shown how to modify commercially available silicon wafers into a structure that efficiently absorbs solar energy and withstands the high temperatures needed for "concentrated solar power" plants that might run up to 24 hours a day.



The research advances global efforts to design hybrid systems that combine solar photovoltaic cells, which convert visible and ultraviolet light into electricity.

"The key point is that to capture sunlight as efficiently as possible you have to do two things that compete with each other: one is to absorb as much power from the sun as possible, but secondly, not reradiate that power," said Peter Bermel, an assistant professor in Purdue University's School of Electrical and Computer Engineering.

PCB007 Highlights

I-Connect007 Launches New Micro eBook Series on Design for Flex and Rigid-Flex
I-Connect007 is excited to announce the release of a new book in our micro eBook series: The Printed Circuit Designer's Guide to…Flex and Rigid-Flex Fundamentals. This micro eBook provides both new and seasoned flex circuit designers with valuable information that will help to assure first-pass success in getting products to market.

Weiner's World—February 2017
IPC APEX EXPO 2017 was the best in five or more years. The 60th annual meeting drew a crowd. The meetings were good and the mood was upbeat. Reports from the show floor indicated new orders from Asia as well as the Americas, and news of increasing business. IPC membership was up in all its regions to more than 4,000.

Eagle Electronics: Success through 'Building Everything'
During a recent visit to Chicago, Editors Andy Shaughnessy and Patty Goldman stopped by Eagle Electronics just outside of Chicago. Chief Operating Officer Brett McCoy gave them a tour of the facility, spoke about the company's plans for the future, and why Eagle is bucking the niche market trend and manufacturing a wide variety of PCBs.

RTW IPC APEX EXPO: Lenthor Engineering Updates Rigid-Flex Capabilities
Lenthor's CFO Oscar Akbar and EMS Manager Matt Kan share ideas with Guest Editor Kelly Dack on the growing flex market and Lenthor's strategy to grow with it.

Vertical Conductive Structures–a New Dimension in High-Density Printed Circuit Interconnect
From our previous conversations, I knew that Joan Tourné was working on a novel high-density interconnection concept. Having eagerly awaited the chance to discuss the technology in detail, I was delighted when he contacted me to confirm that his IP had been secured and that he could now talk openly about VeCS, the Vertical Conductive Structure.

RTW IPC APEX EXPO: Candor Industries' Unique Capabilities Through an Alternative PCB Manufacturing Process
Sunny Patel, Technical Sales Manager with Candor Industries, tells Guest Editor Kelly Dack about their unique manufacturing method that not only improves PCB process turnaround time, but also yields much tighter design constraint quality.

All About Flex: Considering a Flexible Heater?
Custom flexible heaters are available in an infinite variety of sizes, shapes and materials. The most common flexible materials are polyimide and silicone rubber. While silicone rubber has traditionally been thought of as the higher temperature flexible heater option…

EuroTech: Reporting on the Institute of Circuit Technology Spring Seminar
There has long been debate over the exact location of the geographical centre of England, but the village of Meriden has traditionally laid claim to the title, and it offered an appropriate Midlands venue for the Institute of Circuit Technology 2017 Spring Seminar, which followed the Annual General Meeting of the Institute.

Imagineering Authors The Printed Circuit Buyer's Guide to… AS9100 Certification
Imagineering, Inc. recently released their valuable new resource, "The Printed Circuit Buyer's Guide to… AS9100 Certification." Authored by CEO Khurrum Dhanji, "The Printed Circuit Buyer's Guide to…AS9100 Certification" is the first book in an ongoing series of micro eBooks specifically dedicated to the education of the PCB design, fabrication and assembly industry.

Standard of Excellence: Staying Prepared with Operations
Handling the operations of a PCB company these days is a challenge, to say the least. When I started in 1979, we were building single-sided, double-sided, four-layer multilayers, and the occasional six-layer if you really had your act together. We were using FR-4 materials sprinkled in with an occasional polyimide build.

Return Path Discontinuities

by Barry Olney
IN-CIRCUIT DESIGN PTY LTD / AUSTRALIA

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. Rather, one should also consider the presence and interaction of the power distribution network (PDN) and how and where the return current flows. A logic schematic diagram masks details crucial to the operation of unintentional signal pathways vital to understanding signal performance, crosstalk and electromagnetic emissions.

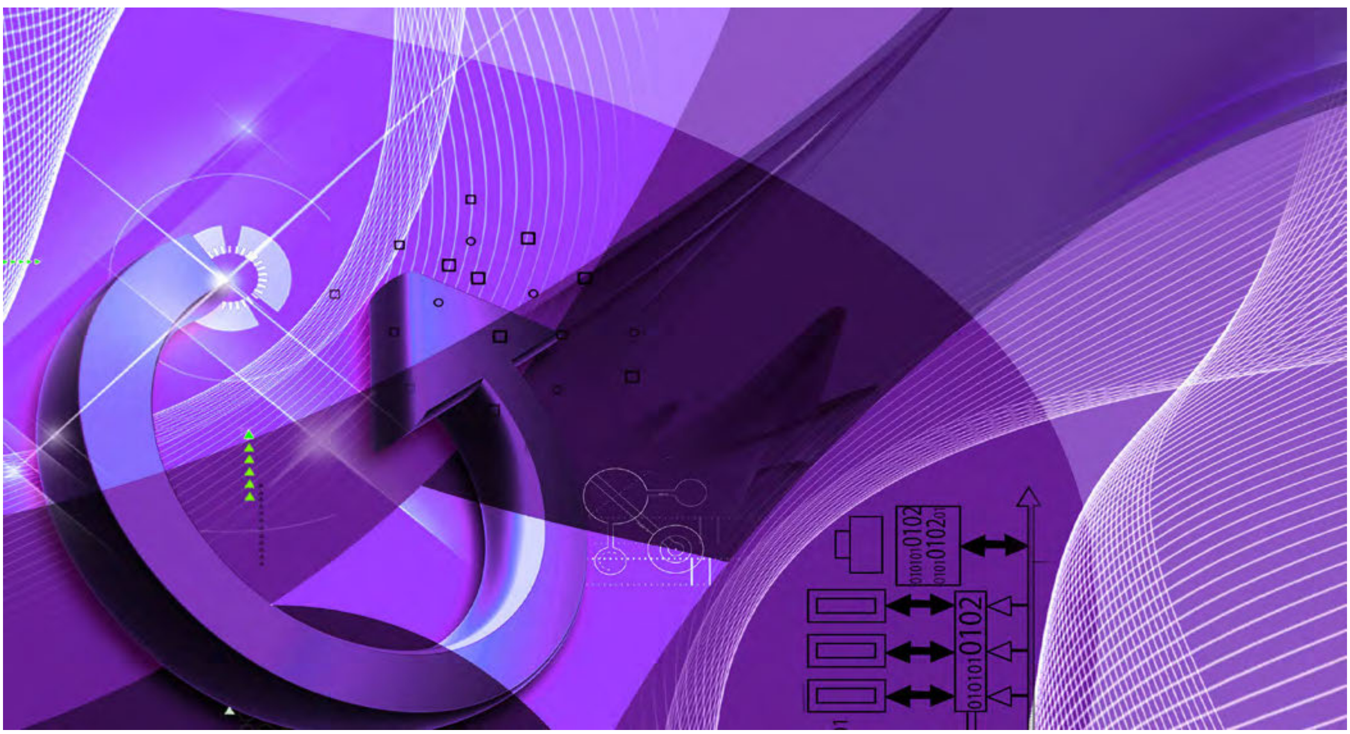
PCB designers, generally, take great care to ensure that critical signals are routed exactly to length from the driver to the receiving device pins, but take little care of the return current path of the signal. Current flow is a "round trip" and the critical issue is delay, not length. If it takes one signal longer for the return current to get back to the driver—around a gap in the plane for instance—then there will be skew between the critical timing signals. Return path discontinuities (RPDs) can create large loop areas that increase series inductance, degrade signal integrity and increase crosstalk and electromagnetic radiation.

Four factors must be considered in order to mitigate the RPDs:

1. Recognize the impact of RPDs.
2. Understand the importance of referencing.
3. Identify the location of the RPDs–path of least inductance.
4. Take corrective action to mitigate the RPDs.

1. Recognize the Impact of RPDs

Ground impedance is at the root of virtually all signal and power integrity problems–low ground impedance is mandatory for both. This



is readily achieved with a continuous ground reference plane, but becomes increasingly difficult with the addition of more and more plane layers on a multilayer PCB. A ground plane serves well as a signal return, provided the ground is continuous under the signal path. But even with a continuous return path, there may be enough voltage drop across the plane to generate a common-mode voltage. And if left unchecked, may escape as electromagnetic emissions via the signal or power/ground conductors. RPDs have a huge impact on supply bounce of single-ended signals. Fortunately, differential signaling dramatically reduces this affect. Serial interfaces also significantly reduce the number of interconnects, which is another advantage over the use of parallel buses for high-speed design.

Small discontinuities, such as vias and non-uniform return paths on a bus, are becoming important factors for the signal integrity and timing of high-speed systems. RPDs produce impedance discontinuities due to the local return inductance and capacitive changes. Impedance discontinuities create reflected noise, contribute to differential channel-to-channel noise and may promote mode conversion. In the case of differential pairs, the transformation from differential-mode to common-mode typically takes place on bends and non-symmetrical routing, near via and pin obstructions, but can also be caused by small changes in impedance due to RPDs.

RPDs also impact on power integrity because of the impedance shift in the PDN. Different techniques must be adopted in order to minimize problems such as ground bounce noise and parallel plate waveguide resonances in multilayer PCB planes.

Furthermore, RPDs tend to cause timing push-outs. A timing push-out (or expansion) is an increase in the flight time of a signal compared to an ideal interconnect. Often seen as a ledge in the rising/falling edge or a diminished rise time at the receiver, these push-outs consume valuable timing budgets allocated to the designer. Any type of non-ideal return path will introduce additional timing uncertainties, into the system, which degrade timing budgets and signal integrity. Therefore, the ability to identify the specific mechanisms that contribute to the performance degradations is essential to a good design methodology.

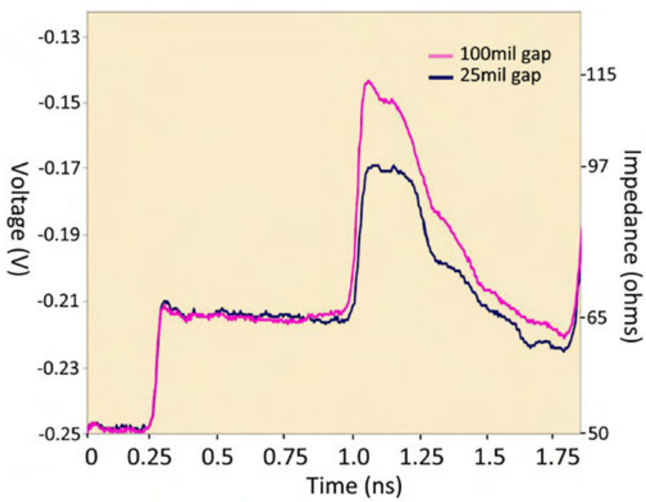


Figure 1: Inductive spike for 25 & 100 mil gaps (source: Byers).

In the case of a split in the reference plane, the most disruptive effect is a significant inductive spike as seen in Figure 1. This plot compares a 25 and 100 mil gap in the return plane. This disruption is caused by the increase in current loop area which corresponds to an increase in inductance following the relationship:

$$L = \frac{\Phi}{I}$$

Where L is the inductance, Φ is the flux defined by the magnetic field, and the area between the trace and plane, and I is the loop current. As the gap forces the return current to diverge, the flux loop defined but the signal trace current and plane current increases, thus increasing the inductance. This spike can pose a serious problem since it will degrade the signal integrity at the receiver, filter the edge rate and increase inter-symbol interference. If this degradation is severe enough, it may cause a false trigger at the receiver or extend the timing enough to violate the setup and hold times.

But most importantly, RPDs typically manifest themselves as intermittent operation and degrade the performance of the product which can be extremely difficult to debug.

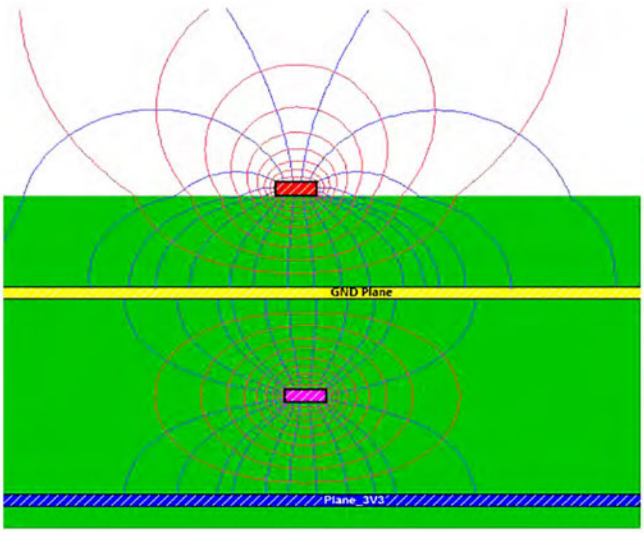


Figure 2: Electric (blue) and magnetic (red) fields (source: HyperLynx).

2. Understand the Importance of Referencing

Each signal layer should be adjacent to, and closely coupled to, a reference plane, which creates a clear, uninterrupted return path and eliminates broadside crosstalk. As the layer count increases, this concept becomes easier to implement but decisions regarding return current paths become more challenging.

Although power planes can be used as reference planes, ground is more effective as local stitching vias can be used, for the return current transitions, rather than stitching decoupling capacitors which add inductance. This keeps the loop area small and reduces radiation. As the stackup layer count increases, so does the number of possible combinations of the structure. But, if one sticks to the basic rules then the best performing configurations are obvious.

Figure 2 shows the electric and magnetic fields emanating from a signal trace in both a microstrip and stripline configuration. Electric fields (blue) terminate when they come into contact with a solid plane, while magnetic fields (red) are shielded by the planes but the fringing fields still tend to radiate from the board edges.

3. Identify the Location of the RPDs

The return current of a high-speed, fast rise time digital signal will always follow the path of least inductance which is directly beneath the signal path. However, RPDs tend to divert the return current increasing the loop area, inductance and delay–which is not desirable. The best way to identify the RPDs is to follow the signal path and imagine the return path closely coupled on the nearest plane.

A via that provides the connection between signal traces, referenced to different planes, creates RPDs. In other words, the return current has to jump between the planes to close the current loop, which in turn increases the inductance of the current loop, thus affecting signal integrity. This return current also excites the parallel plate mode, causing significant EMI. If the reference planes are at the same DC potential, then they can be connected by stitching vias near the signal via transition to provide shorter paths for return currents. However, if the planes are at different DC potentials, then decoupling capacitors must be connected across the planes at these points. In addition, some of the return current flows through the interplane capacitance to close the loop.

Figure 3 illustrates the spreading of return current density across the planes above and below the signal path. As the frequency approaches a couple of hundred megahertz, the skin effect forces the return current to the surface closest to the signal trace. It is important to have a clearly defined return current path and to know exactly where the return current will flow. This is particularly critical with asymmetric stripline

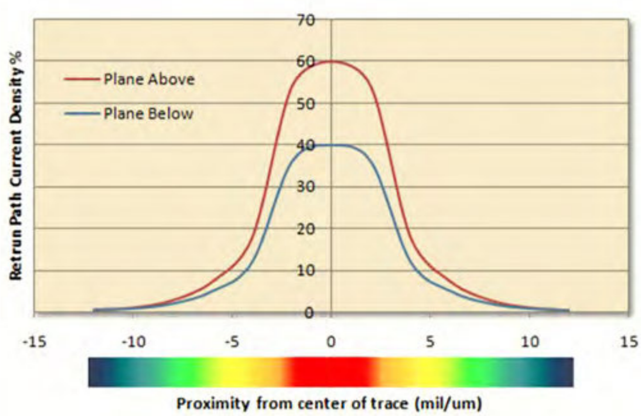


Figure 3: Return path current density for asymmetric stripline (source: iCD Design Integrity).

configurations where one signal layer is sandwiched between two planes. Which plane does the return current flow on?

4. Take Corrective Action to Mitigate the RPDs

Unfortunately, RPDs can never be totally eliminated but we can take steps to minimize the effects significantly. As with PDN planning, it is all about inductance! If the return path loop area is increased, in any way by RPDs, then the inductance will also increase.

There are the obvious rules to follow such as:

- Never allow a high-speed signal to cross a gap or split in the plane. This creates a large return path loop area and tends to radiate.
- Never route a high-speed signal near the edge of the reference plane. The fringing fields may wrap around the edge of the board and radiate.
- Never place an IC over a split plane. The IC substrate is like a miniature multilayer PCB and may rely on a solid plane placed beneath the IC to provide a continuous return path.

If there are sufficient planes in the substrate, or you have the freedom to add more, then the use of a number of central GND plane structures, with signals on both sides, will mitigate the RPDs as the return path will be in the same plane–albeit on opposite sides. As mentioned, at high frequencies the skin effect forces the return current into the surface of the plane, closest to the signal trace, as shown in Figure 4. So, as the signal transitions from one signal layer to the other about the common GND plane, the return current also needs to change planes sides. This is achieved through the outer surface of the via antipad, on the plane, creating only a small RPD due to the variation of impedance between the signal layer and via.

Also, when a signal propagates from the driver to the receiver, it creates noise in the power/ground plane cavity. As a result, energy is being lost to the PDN, creating effects such as RPDs and increasing insertion loss. By reducing the size of the cavity with a thin, high dielectric constant (Dk) material between the planes, ringing at low frequencies is reduced and the cavity resonance moves to the upper band which is above the maximum bandwidth.

Points to Remember

• SSN is a major problem in high-speed systems. But, the underlying issue is really the management of return current paths.

• Current flow is a 'round trip' and the important issue is delay not length.

• Ground impedance is at the root of virtually all signal and power integrity problems–low ground impedance is mandatory for both.

• A ground plane serves well as a signal return, provided the ground is continuous under the signal path.

• RPDs have a huge impact on supply bounce of single-ended signals. They produce impedance discontinuities due to the local return inductance and capacitive changes and cause timing push-outs.

• RPDs typically manifest themselves as intermittent operation and degrade the performance of the product which can be extremely difficult to debug.

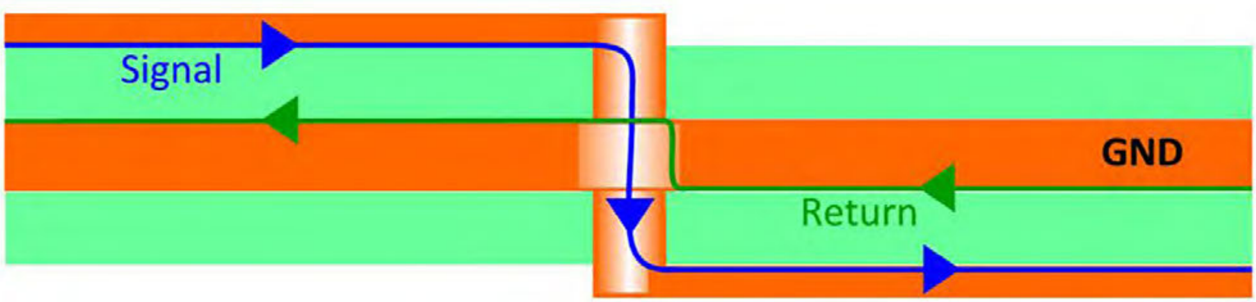


Figure 4: Central GND plane return path structure.

• Each signal layer should be adjacent to, and closely coupled to, an uninterrupted reference plane, which creates a clear, uninterrupted return path.

• Although power planes can be used as reference planes, ground is more effective as local stitching vias can be used, for the return current transitions, rather than stitching decoupling capacitors which add inductance.

• The return current of a high-speed, fast rise time digital signal will always follow the path of least inductance.

• RPDs tend to divert the return current increasing the loop area, inductance and delay–which is not desirable.

• A via that provides the connection between signal traces, referenced to different planes, creates RPDs.

• The skin effect forces the return current to the surface closest to the signal trace.

• It is important to have a clearly defined return current path and to know exactly where the return current will flow.

• RPDs can never be totally eliminated but we can take steps to minimize them significantly.

• It is all about inductance! If the return path loop area is increased, in any way by RPDs, then the inductance will also increase.

• The use of a number of central GND planes, with signals on either side, will mitigate the RPDs.

• By reducing the size of the cavity with a thin, high dielectric constant (Dk) material, ringing at low frequencies is reduced and the cavity resonance moves in to the upper band. **PCBDESIGN**

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2. Power Integrity Modeling and Design for Semiconductors and Systems, by Madhavan Swaminathan.

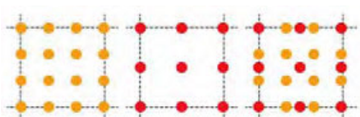
3. Qualifying the Impact of Non-Ideal Return Path, by Byers and Hall.

4. High-Speed Digital Design, by Howard Johnson.

Barry Olney is managing director of In-Circuit Design Pty Ltd (ICD), Australia. This PCB design service bureau specializes in board-level simulation, and has developed the ICD Stackup Planner and ICD PDN Planner software. The software can be downloaded from www.icd.com.au. To read past columns, or to contact Olney, click here.

The Perfect Pattern to Trap Light

Harnessing wave energy by localizing it and suppressing its propagation through a medium is a powerful technique. Now, Alagappin Gandhi and Png Ching Eng Jason from the A*STAR Institute of High Performance Computing have calculated a design that localizes light in tiny loops, within a two-dimensional structure created by merging two lattices of slightly differing periodicities.



The new technique is not limited to light, and may enable the design of systems that can precisely control wave energy in any realm and at any scale.

The ability to create resonators in which light is localized on the surface of a device also has applications in quantum computing components based on light, such as defects in diamond.

Gandhi and Png designed the structures by superimposing lattices of small circular dielectric materials with periods in a simple ratio R:R-1 — for example one lattice is merged with another whose spacing is 4/3 as big, or 5/4, 6/5 etc.

"It creates a two-dimensional effect similar to beats between two waves of very close frequency," Gandhi said. "Where there are antinodes the light is localized in the form of a closed path."

Gandhi and Png ran numerical simulations of the propagation of light in a range of wavelengths slightly below that of the lattice spacing, and calculated the energy band structure.

Resins Maintain a "Pool" of Light Down Under

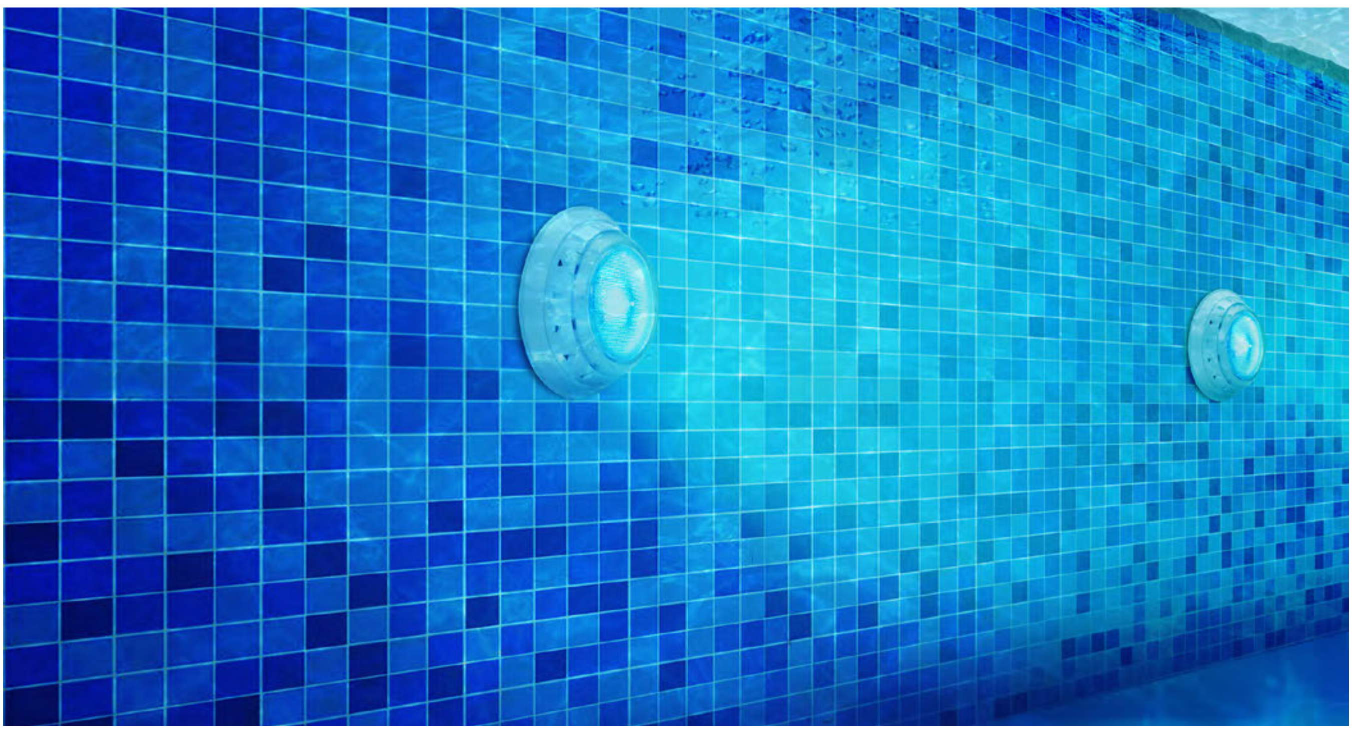
by Alistair Little
ELECTROLUBE

Last month, I departed from my usual format—providing as much information as possible on the subject of resins, their formulations, chemistries, special properties and so forth—to concentrate more on how they are used to solve real-world problems. As I mentioned last month, there is a growing interest in LED lighting, which offers a more efficient and longer-life alternative to halogen, incandescent and fluorescent lighting systems for both interior and exterior applications, as well as providing greater freedom of expression in terms of product design and installation.

Indeed, it is not too strong a statement to say that LED lighting has become a market phenomenon, expected to grow into a $70 billion industry by 2020. Due to turn its market share from a current 18% to 70% in a little over five years, this is one industry whose needs we cannot ignore.

Last month, I described a couple of applications, continents apart, which showed how resins are helping lighting manufacturers, specifically LED lighting manufacturers, to overcome the practical and sometimes technically challenging problems that they frequently encounter. Increasingly, they are turning to companies such as Electrolube for guidance on which potting and encapsulation resin or thermal management product is right for their project.

So, I make no apology for returning to this subject again for this month's column. I'd like to give an account of a project we recently undertook for an Australian customer. They had a number of issues to address with the resin encapsulation of a particular LED lighting unit they had designed for swimming pool illumination, and they've given us the green light (no pun intended) to talk about it.



A couple of pressing problems needed specialist input from our Australasian and UK-based technical teams. Firstly, the lighting unit had to be sealed not just against freshwater, but also saltwater, with saltwater pools being particularly popular in Australia. These pools are not chlorinated in the usual way and swimmers avoid the unpleasant smell of chlorine and its effects on the eyes and skin. Salt resistance was therefore the first imperative when it came to choosing an appropriate resin for this application.

> "Salt resistance was therefore the first imperative when it came to choosing an appropriate resin for this application."

Apart from being able to tolerate a working temperature range of 5° to 40°C, as well as being flame-retardant, the resin colour was another important issue for this project, with a light blue shade preferred for aesthetic reasons. Our customer had been using another company's epoxy resin on this application, but due to the highly exothermic reaction associated with epoxies, some slight deformation of the base unit was occurring as a result of the high temperatures generated during resin cure, which was deemed totally unacceptable. So, our choice was narrowed down to polyurethane, but which product from our large portfolio of polyurethane resins was going to work for this customer?

Polyurethane resins offer excellent water resistance; indeed, some formulated products are designed specifically for marine applications, such as our UR5041, which has proved very effective in applications where the potted unit is likely to be immersed and continually operating in saltwater. Providing exceptional resistance to seawater, this resin has the added benefit of an exceptionally wide operating temperature range (-60°C to 125°C), so it was certainly one to consider for the Australian job.

Then there's UR5083, one of our particularly high-performing resin systems that has the unique ability to "self-heal" if penetrated. This is ideal for applications involving the sealing of submerged units or underwater cabling and wiring where connectors or components need to be passed through the resin after application. The resin maintains contact with the potted unit, while sliding off a wire or connector as it is removed and closing up behind it to provide a moisture barrier.

Another contender was our UR5528 polyurethane resin, which features excellent chemical and water resistance. Our customers have used this on many occasions to protect marine electronics, or other applications where moisture ingress is a potential issue.

We finally decided to offer the customer our UR5097 encapsulation and potting compound. The cured polyurethane has great thermal conductivity, an important property as far as LED lighting units are concerned, and it has a wide temperature range. It is also flame retardant to UL94, which was another of our customer's requirements. As was the case with all the other polyurethane resins we considered, the extremely low water absorption rate of polyurethane was considered the most critical property for this application.

Indeed, UR5097 met all the requirements of this project, with the exception of the colour, that is. Apart from UR5083, which is a light straw colour, our other polyurethane resin contenders for this project were all black as standard, so we had some reformulation to do in order to meet the customer's requirement for a light blue. The colour of a batch of the chosen UR5097 resin was duly altered to the desired shade, and we made sure it was right prior to shipping by matching it against an RAL standard.

With the first production batch of material manufactured to the customer's specification and shipped to Australia, we were confident of a good result. However, during a courtesy visit to the customer by our Australia and New Zealand Manager Mike Woods, accompanied by yours truly, we discovered that there had been a couple of issues with the material.

Over time, sedimentation had occurred and the product was proving increasingly difficult to reincorporate back into the resin mix. Moreover, there was a slight bleed of resin through the gap between the resin and LED unit. With a bit of lateral thinking, the logical solution would be to increase the thixotropic nature of the resin, which would help to slow down the rate of sedimentation to an acceptable level, as well as preventing the resin bleeding so readily through the gap. The polymer used in UR5097 is also highly resistant to the transmission of water even at various pressure differences experienced due to the depth of the water.

A couple of weeks of lab work and testing with a number of different options produced a material that had sufficient thixotropy to slow down the sedimentation and avoid leakage into the gap, while still being easy to mix and pour into the unit. In the end, the actual increase in the mix viscosity of modified resin was only slightly higher than that of the original material.

So, there you have it: a job well done, despite the setbacks, and one that met with the full approval of our customer.

Don't forget to check back next month. **PCBDESIGN**

Alistair Little is global business/technical director for Electrolube's Resin Division.

Researchers Print Promising Two-Dimensional Transistors

Researchers from AMBER and Trinity College in Dublin, in collaboration with TU Delft, have fabricated printed transistors consisting entirely of two-dimensional nanomaterials for the first time. These 2D materials combine promising electronic properties with the potential for low-cost production. This research could unlock the potential for applications such as food packaging that displays a digital countdown to warn you of spoiling, wine labels that alert you when your white wine is at its optimum temperature, next-generation banknote security and even flexible solar cells.

The Trinity College researchers, from the groups of profs. Jonathan Coleman and Georg Duesberg, used standard printing techniques to combine graphene nanosheets as the electrodes with two other nanomaterials, tungsten diselenide and boron nitride, as the channel and separator to form an all-printed, all-nanosheet transistor.

Two-dimensional transistors have been made before with methods such as chemical vapour deposition. While devices created in this manner perform well, the costs of these methods are high. Printable electronics, on the other hand, have until now been mostly based on carbon-based molecules. These molecules can cheaply and easily be turned into printable inks, but such materials are somewhat unstable and have well-known performance limitations.

Collaborating with Toyota's Dr. Sachin Kinge, Dr. Jannika Lauth from the Laurens Siebbeles group at TU Delft tested the electrical transport characteristics of the transistors, proving they combine the best of both worlds. "By using terahertz spectroscopy, we were able to determine the conductivity of the semiconductor materials," said Lauth.

The material that makes up the team's printed electronics consist of many different nanosheets (or "flakes") of varying sizes. A promising next step is to print 2D-structures that are made up of a single nanosheet, which will drastically improve the performance of the printed electronics.

MilAero007 Highlights

Gary Ferrari Earns Dieter Bergman IPC Fellowship Award

In recognition of his ongoing leadership in developing and promoting IPC standards on a global basis, IPC bestowed the Dieter Bergman IPC Fellowship Award upon Gary Ferrari of FTG Circuits.

Imagineering CEO Khurrum Dhanji Discusses New AS9100 Guidebook

I have had many conversations with Imagineering President and CFO Parvin Dhanji, and CEO Khurrum Dhanji, and I always come away very impressed with their dedication to their community, associates and their customers. That's why it was no surprise to me that they teamed with I-Connect007 to publish this long overdue guide to AS9100.

Opinion: Robots and AI Could Soon Have Feelings, Hopes and Rights ... We Must Prepare for the Reckoning

Is artificial intelligence a benign and liberating influence on our lives—or should we fear an impending rise of the machines? And what rights should robots share with humans? Christopher Markou, a PhD candidate at the Faculty of Law, suggests an urgent need to start considering the answers.

Beware the Killer Robots

Autonomous weapons have moved from science fiction to become a clear and present danger. But there is still time to stop them. In July 2015, thousands of researchers working in artificial intelligence (AI) and robotics united to issue an open letter calling for a pre-emptive ban on such weapons.

IPC Volunteers Honored for Contributions to Electronics Industry at IPC APEX EXPO

IPC—Association Connecting Electronics Industries presented Committee Leadership, Distinguished Committee Service and Special Recognition Awards at IPC APEX EXPO at the San Diego Convention Center. The awards were presented to individuals who made significant contributions to IPC and the industry by lending their time and expertise through IPC committee service.

American Standard Circuits' John Rupp Certified as Quality Lead Auditor for AS9100D

American Standard Circuits CEO Anaya Vardya has announced that the company's Quality Systems Manager, John Rupp, has earned his certification as a quality lead auditor for AS9100D.

PCB Maker IMI Installs Micro-Vu Excel Measuring System

IMI Inc. announced today that they have acquired and installed a Micro-Vu Excel 661 UCL Measuring System. This sophisticated machine will complement IMI's current Micro-Vu inspection system and overall inspection, test and measurement capability.

NASA Taking First Steps Toward High-speed Space 'Internet'

The Laser Communications Relay Demonstration (LCRD) will help NASA understand the best ways to operate laser communications systems. They could enable much higher data rates for connections between spacecraft and Earth, such as scientific data downlink and astronaut communications.

Electronics Industry Experiences Technology's Turning Point at IPC APEX EXPO 2017

From revolutionary advancements displayed on the show floor to expert insights conveyed in technical conference sessions and professional development courses, IPC APEX EXPO 2017 provided the learning and connections that helped 4,169 attendees from 39 countries prepare for the future.

Next Generation of Nuclear Robots Will Go Where None Have Gone Before

The cost of cleaning up the UK's existing nuclear facilities has been estimated to be between £95 billion and £219 billion over the next 120 years or so. The harsh conditions within these facilities means that human access is highly restricted and much of the work will need to be completed by robots.

TIE Show Focuses on PCB Design, Signal and Power Integrity

This year, Romania's TIE Student Professional Contest celebrates its 26th year, with the Gheorghe Asachi Technical University of Iasi hosting the PCB design conference and contest April 25-27, 2017.

The TIE show (Interconnection Techniques in Electronics) is the brainchild of Professor Paul Svasta of Politehnica University of Bucharest, Romania. In the 1980s, Professor Svasta envisioned a conference that would draw academics, PCB designers and engineers, and university students together. The first event was held in 1992.

Now, PCB design and design engineering students from colleges all over Romania converge on the TIE show to attend lectures and panel discussions lead by academic and PCB industry representatives.

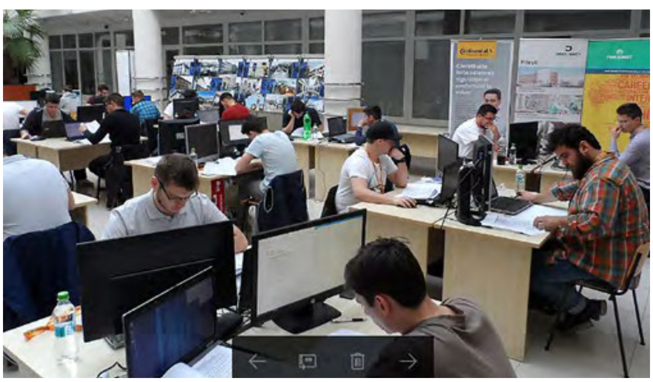
But TIE's biggest draw is the PCB design contest. Students have just four hours to design a circuit for a particular product using a provided BOM. Each student strives to meet a long list of design and product requirements. The best performers are sought after by European electronics companies.

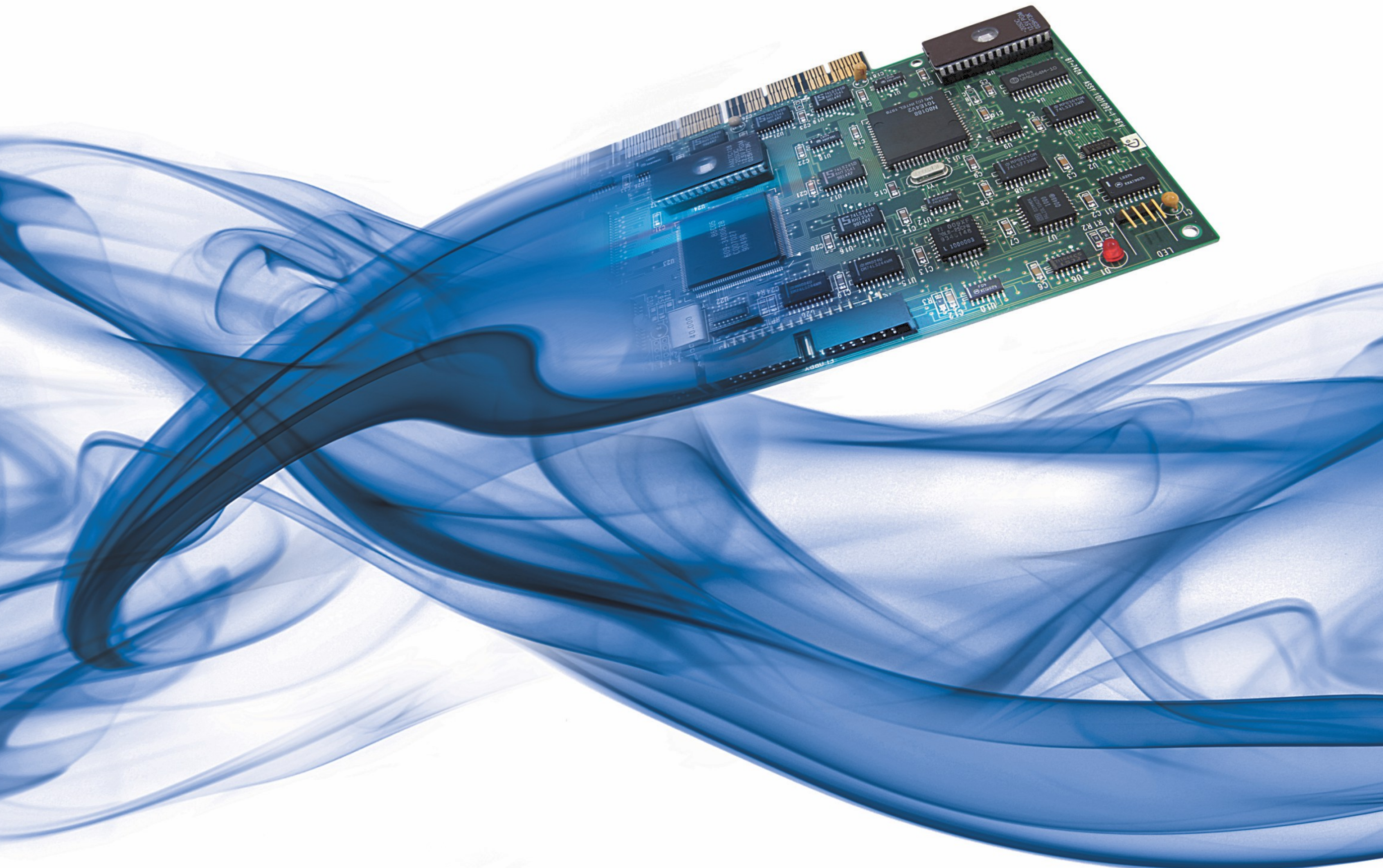
The conference is held entirely in English. TIE has developed into two phases of curriculum: the "classic" TIE focused on an introduction to PCB design, and TIE+, which is dedicated to signal and power integrity this year. TIE+ also attracts graduates and PhD candidates, in addition to undergrads. Both phases are evaluated by representatives of the industry and engineering teaching staff.

TIE is seen by industry as a proving ground for future PCB designers and design engineers.

"Hence, TIE is not a simple PCB design student contest anymore, but a real PCB designer certification respected by the industry," said show planner Gaudentiu Varzaru, a researcher with Politehnica University of Bucharest. "Industry representatives belonging to the TIE Industrial Committee validate the competency of the participants through appropriate diplomas at the end of both phases. These diplomas will become a real passport for their future professional activities."

For more details, visit [www.tie.ro.](http://www.tie.ro)





INTERVIEW

Altium Focuses on the Designer First

by Judy Warner
ALTIUM

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.

***Judy Warner**: Lawrence, before we get started, why don't you tell us a little bit about your background.*

Lawrence Romine: My background is about 16 years in professional business. My father was an engineer. Grew up working in the garage with my father starting at an early age. We restored British sports cars—MG, Triumph, Jaguar, and motorcycles. It's still what I do for fun.

I have a lifelong passion with aviation. Joined the Navy out of high school and got into avionics and was here at Miramar in the F-14 business, which was very exciting. I finished school and became a design engineer in the audio industry. This was for the audiophile business, which is really much more art than science. I did that for just a handful of years, but then got into the semiconductor business.

I got a job in the semiconductor business and I was selling mostly Xilinx components with a now-purchased distributor called Insight. I did that for four or five years and then moved over to software. I did that for the same reason you made some adjustments in your career. It really became difficult to track business into China and I was looking for an opportunity to get into something that offered a little more instant gratification.

When I engage with a customer at a block diagram level, we're going to talk about their system and just roughly what technologies they are going to have on this design. Back then they would give you a completion date, a time-to-market date, and it was typically 18 months to two years, and I always added at least six to nine months in my forecasting. I'm sure you have had a similar experience.

***Warner:* Yes, I was in the EMS industry selling to the military. Longest lead times on the planet. You can work a very long time for something only for it to go "poof." But when it is payday, payday's really good, but it takes a long time to get there.**

Romine: Absolutely, and it was a 10% hit rate. I'd say you need to call on 100 people to get 10. But supporting all 100 as diligently as you do the 10, and really the idea was to assist them in meeting and realizing the project coming to fruition. It just rarely happened. That encouraged me to look for a software opportunity and I ended up here and it's been now 11 years at Altium.

***Warner:* That's quite a path. In our industry, we all seem to take a long and winding path to get where we end up, but almost everyone has an interesting story.**

Romine: Even when I went into engineering, the goal was always to be in the business end of it because that was what I saw my father doing. It just appealed to me. He was very tied to the things that I was interested in, which was the technology, the tinkering, the exploration, and the creative portion of it, but at a much more of an abstract and practical application level.

But if I talked to our salespeople, a lot of them are marketing people; absolutely I don't think any of them really saw a career in the technology business, certainly not in the EDA or CAD space. However, I would argue that none of the users got into this business by accident.

***Warner:* Give me the typical bio of an Altium customer.**

Romine: If you ask engineers if they've ever met a release date and they say yes, they're either lying or they moved the goal post. But when we talk about our customers, as I've said, I don't believe any of them got into this business by accident. It's almost like you're born into this business an engineer or a designer.

***Warner:* I think that's right.**

Romine: When they first come into the business, "civilians" as I call them, I'll just ask them what their perception of an engineer or a designer is, and overwhelmingly you get responses that they're reserved, they're quiet, they're antisocial. You know, you get "geek," "nerd," and all these other names. I don't think those are derogatory terms. Honestly, I've always embraced that term.

They have that perception because they realized at a pretty early age that, when they talked about what motivated them, the things they were interested in, and the questions they asked about the world around them, the average civilian didn't know what the hell they were talking about.

That ties back into my original story about growing up questioning everything. It was "How does that work?" Take it apart and find out. I don't think that is an uncommon trait amongst this community of users. These are people that grew up saying, "I bet I can make that go faster. I can make it go higher. We can make it go farther. What if we tried this approach versus this approach?" It's really much more of an innate lifestyle choice.

Overwhelmingly, they realize that the average person walking around doesn't really know what it is they're talking about. As a natural defense mechanism, they purposefully sort of leave details out. That is heavily contrasted when you see a group of engineers together. What you see as the common trait amongst these people is really a curiosity, a cynicism, and a passion for what it is they do. I would dare say it's even much more of an art that's wrapped in science.

***Warner:* I agree. I'm sure you would include in the picture you're painting the PCB designers and engineers who are artists and musicians.**

Romine: Absolutely.

***Warner:* It's the same part of the brain, and you see that. That sort of social awkwardness, I don't find that to always be true. It just depends on what you're talking about.**

Romine: Keep in mind, I don't believe that the engineers see themselves that way. As an example, when I first got into the semiconductor business at 25, this was sort of a lifelong…I don't want to use the word dream, but it was my aspiration. I wanted to be in engineering, specifically in some sort of business field related to engineering, and the semiconductor business was, especially in those days, a great hybrid role. We still got to talk about the technology, architecting systems and that sort of thing, but there was a business element to it that appealed to me.

When I first got that job, Xilinx was the marquee name, still is. A leader in the industry. Any time someone asked, "Hey, what do you do?" Of course, my response was very enthusiastic. "Oh, well, I'm glad you asked! I sell programmable data rays and synthesis tools, and floor planning tools, and, and, and, and…" It was pretty quickly that you would see the glaze. Like, "What the hell are you talking about?" It didn't take very long that my response to "Hey what do you do?" had morphed into "Well, I'm in sales."

The flip side of that is when you run into someone who is in "the club." When you meet someone, "Oh, I'm in sales." "Well, what kind of sales?" "I'm in technical sales." "Software or hardware?" You think, "Oh, well, maybe this person might kind of know what I'm talking about."

***Warner:* You start speaking in full sentences all of a sudden.**

Romine: And then all of a sudden there's the passion that we're talking about. That's really who we've always done business with. What we talk about is that nobody becomes an engineer or a designer by accident. I mean, there are some exceptions, but overwhelmingly the personas that we deal with are doing what they've wanted to do, and it's always what they've wanted to do. It's an emotional experience for them when they first hand-soldered something together, maybe their senior project. For me, it was more around the cars that we built. That first time, it starts is like an emotional experience. The path to becoming a professional engineer requires a lot of education, and a lot of difficult courses. They get through that, though, and they become professional engineers and professional designers.

Unfortunately, what happens is that engineers realize that the majority of their day is not actually designing. We have research that says 61% of their day is on non-design-related tasks. It's looking for information, disseminating information, filling out paperwork, managing a bill of materials. It's going through some rigorous release checklist that always will generate an error, that requires you to go back and redo, redo, and redo. I think that is very frustrating; it was for me.

***Warner:* You're talking about things like pouring through datasheets, talking about if a part is obsolete or at risk of being obsolete, the libraries, etc.**

Romine: Yes, 100%. As I said, I worked in distribution so the engineers really were forced to have a conversation with me. In those days, it was a little different because the internet wasn't quite as prolific as it is now with regard to data and roadmap information. Of course, when you're talking about long design cycles of a couple of years, they need to know what's coming down the pipe as it relates to field programmable logic. What's the newest device and what's coming?

But overwhelming, to your point, a lot of it was getting price break information, volume price break information, lead time information, second source information and these sorts of things. Now the engineers had those conversations, but they didn't want to. That's a great example of engineers being sort of forced to participate in a non-design related task. That's all time, by the way, that they're spending not designing anything whatsoever, which is what they love, but also secondarily is detrimental to the organizations they work for.

***Warner:* Why does Altium pay so much attention to the individual designers? You're not talking about huge OEMs.**

Romine: Well, we pay attention to them because those are other people that buy our products. If we look at the evolution of the industry, everybody starts out selling one product or one piece of software, for example, to an individual with an aspiration of moving on from that into a strategic type of selling environment where we're doing business with these huge OEMs. The reality is just by the nature of that we were always the smaller player in the industry. Of course, that's all now changed. We, secondarily, did not have a broad offering. This is what we do: printed circuit board design.

It allowed us to really focus by necessity, and by design, on those users. The reality is we didn't have a portfolio of 20 products to go into an executive's office and say, "Let's build some strategic solution for your organization." We were always doing business, you could call it business-to-business, but it was really what I would coin a new term called BTU, which is business to user.

Now secondarily to that and the byproduct of that are the more corporate oriented goals: time to market, product and development costs, and product quality. Those are the three biggies. And overwhelmingly we find our users are aware of that, but that's not the emotional connection they have with what they do. It's "I want to design something." I say is it's a disease in these organizations, with symptoms that manifest themselves in two different ways. If you're an executive, it's time-to-market, it's product and development costs, and quality targets. If you're a user, it's all just a big distraction from the thing you really want to do.

***Warner:* But what specifically does Altium do that gets designers out of that minutiae and able to spend more time doing the things that they love, which is designing?**

Romine: Overwhelmingly, it's encapsulating more of the design process into our single application, which is Altium Designer. Then taking that directly to the user space and developing technologies that reduce those non-design oriented tasks, taking those away and automating those wherever possible.

***Warner:* You said that 61% of their time is spent doing non-design related activities. Do you have an idea what percentage of time that frees up? I know that's very hard to measure.**

Romine: It is, and we tried to measure it once. In our first really steep growth curve that we had, in the 2007 – 2010 timeframe, we surveyed our customers and at that time we were counting the number of competitive users we were acquiring. We kept counting and we got over 2,000 new users in the course of a year from verifiable competitive users. These were people using Cadence or Mentor products primarily. We surveyed them and asked how many of them had experienced an improvement, and it was overwhelmingly in the 80% range.

Of those users, we surveyed what percentage of productivity they had seen and 86% of the group they saw productivity enhancements said it was 200%.

***Warner:* Wow. That's a shocking number.**

Romine: Yeah, it is. That's why I don't care to use it too much, but it's significant. We were public with this data. Just to give you an example, Judy, you look at the anecdote I told you about being in distribution, dealing with engineers, disseminating data to them, getting price breaks, lead times, and forecasts, all this sort of supply chain oriented stuff, and when

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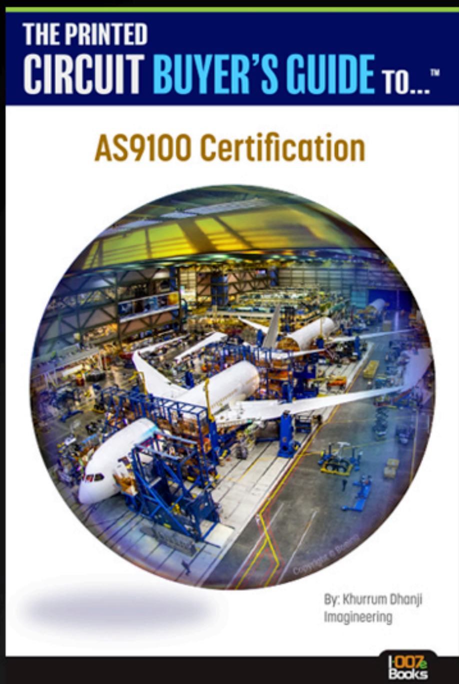

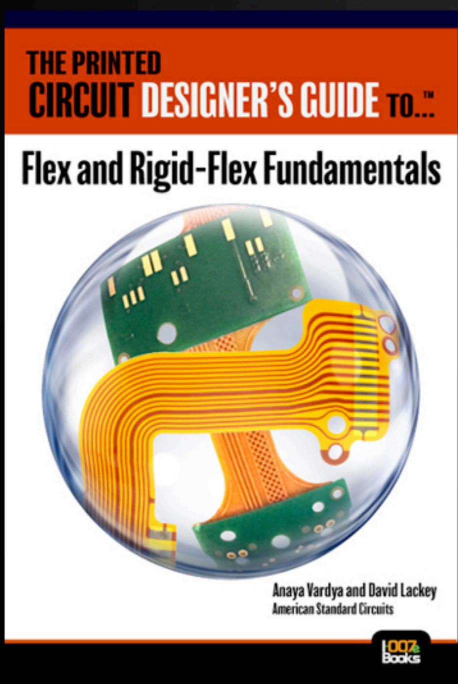

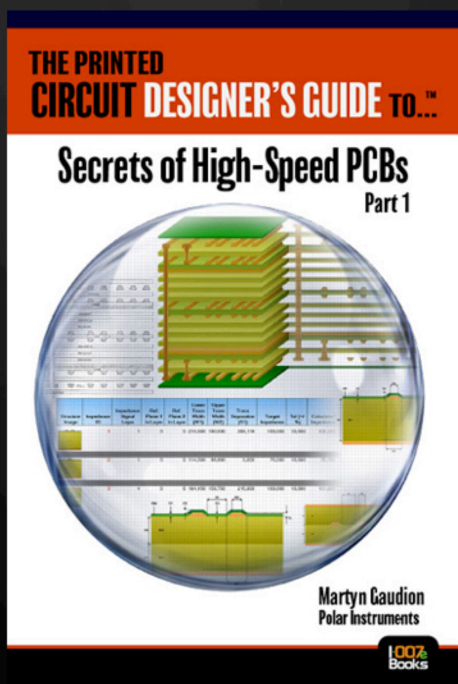

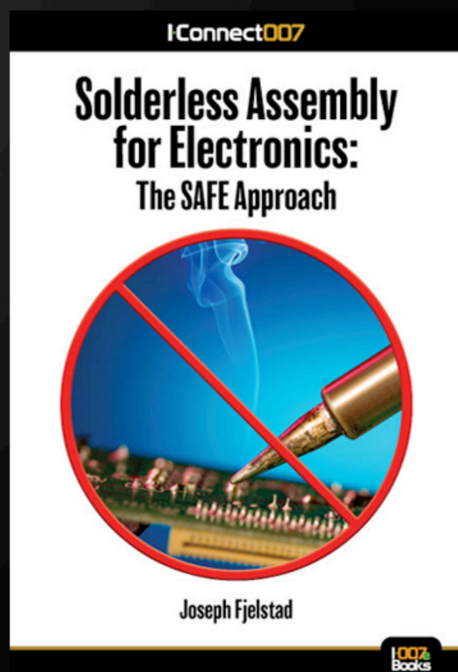

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we first started bringing supply chain information into the design environment, just like you, I would go to trade shows and talk to engineers. Of course, I'm a marketing and salesperson at heart so I would give them an example of some of the things we could do for them.

***Warner:** Well, I can see why you would get fans from doing that. You're taking them out of the mud so to speak. Now I think the number that Chris Donato had told me is you sold around 5,000 seats in 2016?*

Romine: Correct, in the last fiscal year. It's about one an hour.

***Warner:** It's hard to get my head around that, but what I also know is that that your package is a lot less expensive than some of your competitors, correct?*

Romine: Well, I'm not going to use the term "value" because I have a certain definition of value but other people think it's one of those cheap words. But I will say bang for your buck. The proposition is unbelievably valuable. When we look at it for what you get for what you pay and considering what we're really eliminating. For example, Draftsman is our new fabrication drawing tool. It's a drawing tool that runs inside of Altium Designer. That's a great example of us eliminating an entire post process. This is really at the heart of everything we've really brought to the market space, eliminating that in between stuff.

When you look at engineers' frustrations in releasing products on time, they're never going to tell you it's because they couldn't actually design the PCB. They're never going to tell you it's not because they couldn't draw the schematic. It's always something in between. We look at Draftsman as a great example of that.

What I say is that the essence of design is redesign. That's really what we enable our users to do, to not be penalized for being creative, and being explorative when we talk about creating something really cool.

***Warner:** Which is where all good technology that gets to market comes from.*

Romine: Of course. Well, look at it this way, Judy. Again, I'm a gear head. Given my choice, I would have a motorcycle shop or a hot rod shop, or something along those lines. You take, for example, a disc brake system on a car. It looks overwhelmingly simple. It's a rotor, two pads with a caliper on it. You look at that and you say well, shouldn't it have always been done that way? But I think the essence of sophistication in design is simplicity. That's what we've been able to do because this is the industry we work in and where 90+% of our revenue comes from. Therefore, we're able to invest in specifically this business.

We acquired about eight companies after our public offering. Because of our singular focus on this business, we were able to look at the technologies that we acquired and ask, "How do we make this simple? How do we make this non-punitive to our customer base?"

***Warner:** So simplicity, again, along with focus, really is what got you where you are and sort of defining your customer as the average Joe layout guy. Obviously, judging by the number of seats you've sold, you've hit a chord with the market.*

Romine: There are a number of things going on. We have a huge segmentation of our users that are what I call "Joe from Joetronics." And the appeal that brought us into Joetronics is the same appeal that's brought us into some of the well-known OEMs. Early days in my career here at Altium, I was a salesperson. I'd call all these people up and talk to them about the design process and what they're doing. You'd find in our database some of these marquee names who had a couple licenses of Altium Designer. You'd call them up and they'd say that they're standardized on brand X or standardized on Y. That's interesting, then why is it that you have Altium Designer there as well? Well, they use Altium Designer when they want to do something fast. Of course my feeling was, "Don't you want to do everything fast?" But that's what we've seen is, again, us always focused on the user, and that there was a natural adaptation.

***Warner:** Why would they use something else? Were there features? Now here I will pause to say I have*

heard amongst the grapevine that some users were frustrated with your router at one point, but I know ActiveRoute might do some things to remedy that, but why would they use something more cumbersome and not as easy and elegant?

Romine: It comes down to what we discussed in the last bullet point, which was that it was an executive mandate. In particular, we also find with the bigger market segments or business focuses of some of our competitors that the PCB side is just to check a box. To say that they have that, too, and that they are a total solution provider. Often times it's used as a lever to sort of add value to the bigger, more interesting piece of the business segment.

However, what we have seen is the user space is changing with the younger generation of designers and engineers that are coming into the industry. They're much more familiar with finding information on the internet, and getting excited about a technology.

Warner: How do you support such a broad user base? How do you support 5,000 seats after you've sold them?

Romine: Well, we do it. Our whole sales and support operation is built around a transactional business model. Yes, the product is not inexpensive, but we definitely do sell it in a transactional way. This ties into the documentation we provide, our online presence, but we have geographically located support engineers and we support these customers 100%.

Warner: Interesting. Thank you so much.

Romine: Thank you, Judy. **PCBDESIGN**

Quantum Communication: How to Outwit Noise

How to reliably transfer quantum information when the connecting channels are impacted by detrimental noise? Scientists at the University of Innsbruck and TU Wien (Vienna) have presented new solutions to this problem.

Scientists have conducted quantum communication experiments for a long time. "Researchers presented a quantum teleportation protocol already in the 1990s. It permits transferring the state of one quantum system to another by using optical photons," says Benoit Vermersch, postdoc in Peter Zoller's group at the University of Innsbruck.

Superconducting qubits, in particular, are promising elements for future quantum technologies. They are tiny circuits that can assume two different states at the same time. Contrary to conventional light switches that can be either turned on or turned off, the laws of quantum physics allow a qubit to assume any combination of these states, which is called quantum superposition.

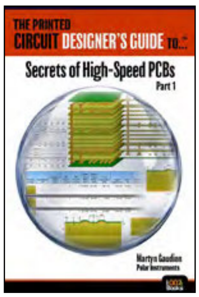
To transfer this quantum state from one superconducting qubit to another requires microwave photons, which are already used for classic signal transfer. Reliably transferring quantum information via a microwave regime has been considered impossible as the constant thermal noise completely superposes the weaker quantum signal.

The two research groups have now shown that these obstacles are not impossible to overcome as previously assumed. In collaboration with teams from Harvard and Yale (USA) they have been able to develop a transfer protocol that is immune to the inevitable noise.

"We cannot prevent the thermal noise that develops in the quantum channel," says Benoit Vermersch. "What is important is that this noise affects both oscillators on both ends in the same way. Therefore, we are able to exactly separate the detrimental effect of the noise from the weaker quantum signal through precise coupling to the waveguide."

Recent Highlights from PCBDesign007

1 I-Connect007 Launches The Printed Circuit Designer's Guide to…Secrets of High-Speed PCBs – Part 1



I-Connect007 has released the next book in the micro eBook Design series, *The Printed Circuit Designer's Guide to… Secrets of High-Speed PCBs – Part 1*, by Martyn Gaudion of Polar Instruments. Written to assist EEs, PCB designers, procurement professionals, and PCB fabrication professionals and managers at all levels, this book offers the greatest benefit to design and procurement people by helping them understand what can realistically be achieved in the final product.

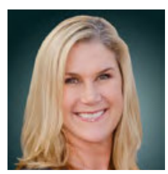
2 Rigid-flex Design Tips and Best Practices

While the traditional "design-separately-then-assemble" approach minimized potential issues with the flex portions of the product, it also had several inherent disadvantages. These include the cost associated with the physical connectors; the space required for the physical connectors; the need to properly manage interconnects that have to transition between the separate rigid and flex PCBs; and, of course, the time and cost associated with assembly.

3 EMA PCB Clustering for OrCAD Accelerates Design Reuse and Component Placement

PCB Clustering for OrCAD resides directly in the OrCAD PCB Editor canvas. Related components are typically grouped together in the schematic. PCB Clustering can leverage this information to auto-generate tiled placement clusters. These clusters can be based on hierarchy, pages, reference designator prefixes/suffixes and/or ROOM properties defined in the schematic. This allows designers to get a quick logical grouping in the physical realm, enabling faster placement.

4 Perpetual or Subscription EDA Tool Licenses? That is the Question



I've been wondering about the pros and cons of perpetual vs. subscription EDA software licenses. I wanted to learn firsthand from PCB designers what kind of benefits they received and challenges they faced as a result of how EDA companies offered design tools. I reached out to a variety of sources to get a broad slice of insight into this evolving issue, and thus began my trip down the EDA software rabbit hole.

5 Zuken Partners with Nano Dimension to Develop Seamless Design to Manufacture for 3D Printing

Zuken and Nano Dimension are working together to advance the 3D printing user experience and prototype turnaround times. Nano Dimension, a leader in electronic printing technologies, will take advantage of the support for implementing electronic technologies provided by Zuken's market-leading, native 3D, system-level design solution, CR-8000 Design Force.

6 Catching up with Polar Instruments' Geoffrey Hazelett

Product specialist Geoffrey Hazelett discusses some of the latest developments at Polar Instruments, including a new tool that will allow fabricators to determine how copper roughness will affect the end-product. He also talks about Polar's upcoming eBook on signal integrity, soon to be published by I-Connect007. Talented young technologists like Geoffrey are the future of our industry.

7 Siemens Closes Mentor Graphics Acquisition

With the recent closing of its acquisition of EDA software leader Mentor Graphics, Siemens sets out to underscore the significant customer value it envisions for both electronic systems and IC design tools. Mentor is now part of Siemens' PLM software business, making the combined organization the world's leading supplier of industrial software used for product design, simulation, verification, testing and manufacturing.

8 New Functionality Improves Designer's Productivity

One of the main details lacking in today's PCB design software is the flow of impedance control from design capture through to board fabrication. If the impedance of all the required technologies, used in the design, is determined up-front at the time of capture, the engineer's intent should be preserved and flow through to downstream tools. However, that scenario rarely happens.

9 IPC Designers Council Orange Co. Chapter Holding Lunch 'n' Learn April 19

The Orange County Chapter of the IPC Designers Council is holding a Lunch 'n' Learn event on April 19 at JT Schmid's Restaurant & Brewery in Anaheim. This meeting features two speakers and takes place from 11:30 am - 1:30 pm in the Regan Room at JT Schmid's. Cost is $15 at the door to cover the cost of lunch.

10 Cadence's Zhen Mu Discusses Her Power-Aware Analysis Solution White Paper

Zhen Mu, senior principal product engineer with Cadence Design Systems, and Brad Griffin, product marketing director for Cadence, sits down with Andy Shaughnessy to discuss Zhen's new white paper, "Power-Aware Analysis Solution."

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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.

SMTA Atlanta 21st Annual Expo
April 19, 2017
Duluth, Georgia, USA

TIE (Interconnection Techniques in Electronics) Show
April 19, 2017
Iasi, Romania

14th Electronic Circuits World Convention (WECC)
April 25–27, 2017
Goyang City, South Korea

KPCA Show 2017
April 25–27, 2017
Goyang City, South Korea

NEPCON China 2017
April 25–27, 2017
Shanghai, China

IPC Reliability Forum: Manufacturing High Performance Products
April 26–27, 2017
Chicago, Illinois, USA

IMPACT Washington D.C. 2017
May 1–3, 2017
Washington, D.C. USA

What's New in Electronics Live!
May 9–10, 2017
Birmingham, UK

Thailand PCB Expo 2017
May 11–13, 2017
Bangkok, Thailand

JPCA Show 2017
June 7–9, 2017
Tokyo, Japan

IPC Reliability Forum: Emerging Technologies
June 27–28, 2017
Düsseldorf, 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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